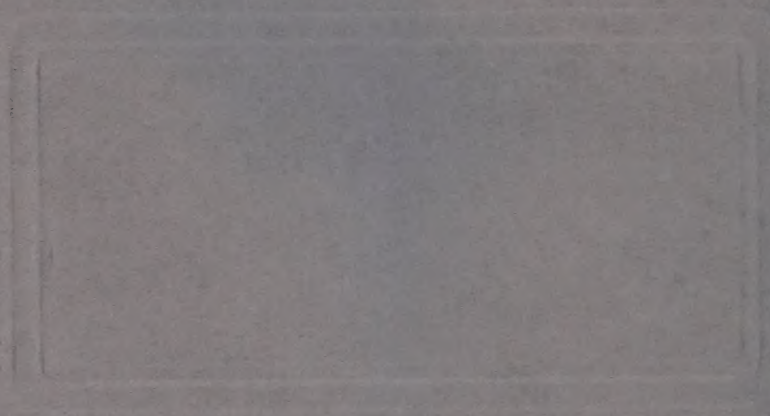
MODEL 220
FAULT LOCATING
WHEATSTONE BRIDGE
INSTRUCTION MANUAL

ELECTRO-MEASUREMENTS, INC.
7524 S.W. MACADAM AVE.
PORTLAND 1, OREGON



INSTRUCTION MANUAL

ESI MODEL 220

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ELECTRO-MEASUREMENTS, INC.
7524 S. W. Macadam Avenue
Portland 19, Oregon

December 1957

esi MODEL 220 BRIDGE
ELECTRO-MEASUREMENTS, INC.
BRIDGE 220
MURRAY
VARLEY
RESISTANCE
EXT. GALV
INTERNAL BAT
EXT. BAT
X1
X2
RH
GND
INCREASING SENSITIVITY

1. INTRODUCTION

The ESI Model 220 is an ultra compact portable Wheatstone Bridge. It has provision for both Murray and Varley loop tests so that it is especially useful in the field as a fault locating bridge. It features high accuracy, wide resistance measuring range, small size, light weight and great versatility. It is completely self-contained including its own battery and galvanometer. The DEKASTAT portion of the bridge may be used independently as an accurate four decade resistance box.

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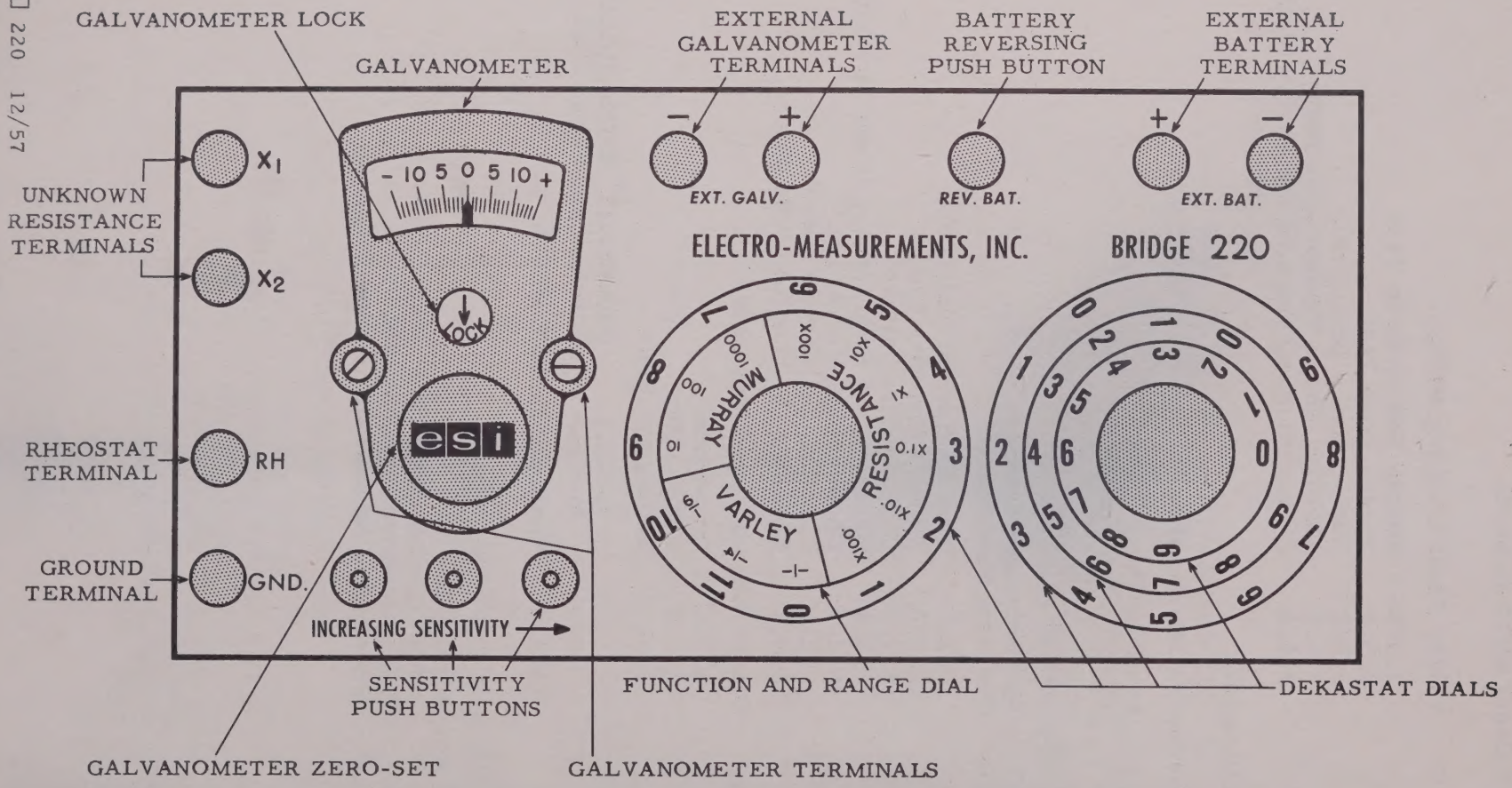

MODEL 220 FAULT LOCATING BRIDGE

2. CONTROLS

2.1 UNKNOWN RESISTANCE TERMINALS: The two terminals in the upper left-hand corner of the bridge, labeled X_1 and X_2, are for connecting the unknown resistance to be measured.

2.2 RHEOSTAT TERMINAL: The terminal at the left-hand edge of the bridge panel, labeled RH, is for convenience in using the DEKASTAT® decade resistor independently. The DEKASTAT® is connected to the RH and X_2 terminals.

2.3 GROUND TERMINAL: The terminal at the lower left-hand corner of the bridge, labeled GND, is used for connection to the return path in MURRAY and VARLEY loop tests. It is not connected to the bridge circuit for resistance measurements. There is no connection to the bridge chassis.

2.4 SENSITIVITY PUSH BUTTONS: Each of the three push buttons at the bottom edge of the panel first turns on the battery and then connects the galvanometer into the circuit. The button pressed determines the galvanometer sensitivity. A quarter turn on any button locks it in the "on" position.

2.5 EXTERNAL GALVANOMETER TERMINALS: The two terminals at the top edge of the panel, labeled EXT GALV, are for connecting an external galvanometer to the bridge in order to have a greater sensitivity than that afforded by the internal galvanometer. Pushing either of these terminals to connect an external galvanometer automatically disconnects the internal galvanometer.

2.6 BATTERY REVERSING PUSH BUTTON: The spring-return push button at the top edge of the panel, labeled REV BAT, is used for momentarily reversing the polarity of the voltage applied to the bridge circuit.

2.7 EXTERNAL BATTERY TERMINALS: The two terminals in the upper right-hand corner of the bridge panel, labeled EXT BAT, are for connecting an external battery or power supply to the bridge. For high resistance measurements, the bridge sensitivity can be increased by providing a voltage higher than that of the internal batteries. Pushing the right-hand EXT BAT terminal automatically disconnects the internal battery. A stud in the lid of the instrument pushes this terminal to disconnect the internal battery when the lid is closed.

2.8 FUNCTION AND RANGE DIAL: The inner dial of the left-hand dial group selects from six resistance ranges, three VARLEY loop ratios, and three MURRAY loop ratios.

2.9 DEKASTAT® DIALS: The outer dial of the left-hand dial group and the three dials of the right-hand dial group comprise the DEKADIAL® assembly which controls the DEKASTAT® decade resistor. The dials may be set to any number between 0 to 11,999. The dial reading represents the DEKASTAT® resistance in ohms.

2.10 GALVANOMETER: The meter on the left-hand side of the bridge panel is a sensitive galvanometer which is used for indicating a bridge balance.

2.10.1 GALVANOMETER TERMINALS: The two mounting screws are connected to the galvanometer terminals so that it may be easily connected to other external circuits. One terminal of the galvanometer is disconnected from the bridge circuit when all the sensitivity push buttons are up.

2.10.2 GALVANOMETER ZERO SET: The large knob on the galvanometer can be rotated for mechanically positioning the galvanometèr pointer.

2.10.3 GALVANOMETER LOCK: When the lock button is pushed in the direction of the arrow, the galvanometer suspension is rigidly supported for protection during transportation. The lock should always be applied when the instrument is not in use.

3. OPERATING INSTRUCTIONS

3.1 What the Bridge Measures

Resistances are measured by means of a conventional Wheatstone Bridge. The MURRAY and VARLEY loop circuits use the Wheatstone Bridge circuit to compare line resistances. Because of line uniformity it is possible to locate crossed wires or ground faults by such resistance comparisons.

The VARLEY Bridge can be used as a continuity checker for finding short or open circuits.

WHICH BRIDGE CIRCUIT SHOULD BE USED

TEST	CONDUCTOR RESISTANCES			WHAT MUST BE KNOWN	BRIDGES BALANCES
MURRAY LOOP	Low Resistance Loop	Good and faulty conductors have same resistance		1. Length of faulty wire, ℓ	One Balance
ALTERNATE MURRAY LOOP		Good and faulty conductors have different resistance		1. Feet per ohm of faulty wire, B	One Balance
MODIFIED MURRAY LOOP				1. Length of faulty wire, ℓ	Two Balances; one from each end
SIMPLE VARLEY LOOP	High Resistance Loop	Resistance of faulty conductor is known	Good and faulty conductors have same resistance	1. Length of faulty wire, ℓ 2. Resistance of loop, R	One Balance
VARLEY LOOP			Good and faulty conductors have different resistance	1. Length of faulty wire, ℓ 2. Resistance of loop, R 3. Conductor resistance, Y	One Balance
THREE VARLEY LOOP		Resistance of faulty conductor is not known		1. Length of faulty wire, ℓ	Three Balances

3.2 CONTINUITY CHECKING

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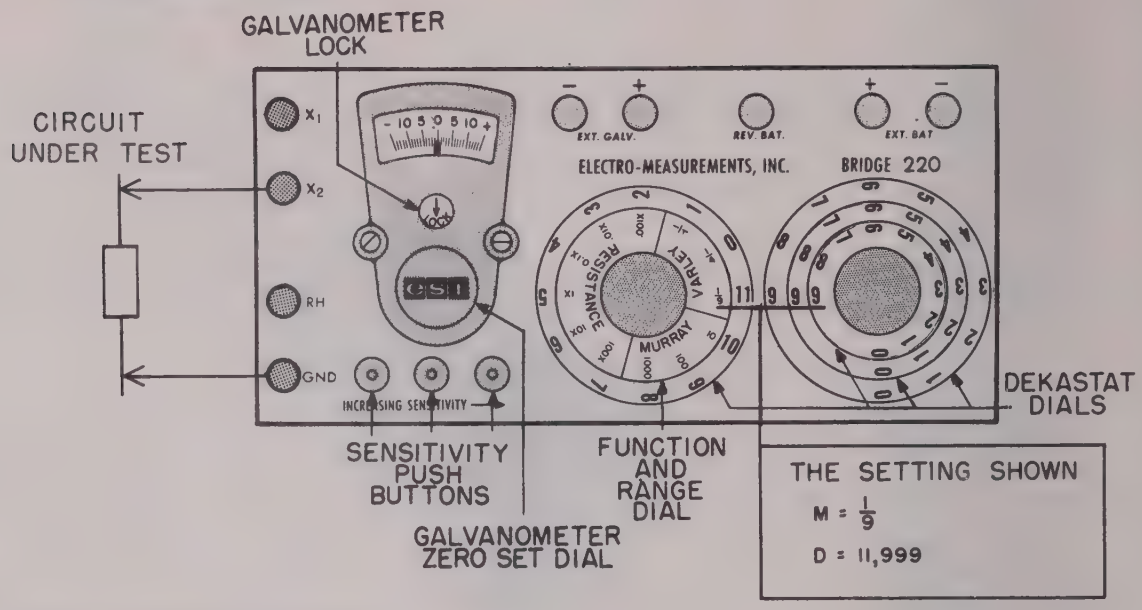


3.2.1 BASIC INSTRUCTIONS

1. Connect probes to terminals X_2 and GND. — This places them in the right part of the circuit.

2. Set the DEKASTAT® dials to read 11,999. — With this setting, even high resistance shorts and crosses can be detected (1 dial division deflection for about 200K ohms)

3. Release the GALVANOMETER LOCK and check the zero position of the pointer. — The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.

4. Set the FUNCTION AND RANGE dial to the 1/9 VARLEY range. — This permits high resistances to be detected without causing undue deflection for low resistances.

5. Depress the center SENSITIVITY PUSH BUTTON. — This connects the GALVANOMETER, provides the proper sensitivity, and turns on the battery circuit. The sensitivity button may be locked down if desired by pressing then rotating 1/4 turn.

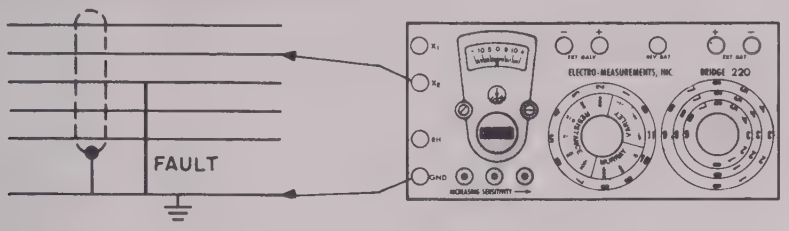
6. Use probes to check opens or shorts.

Sensitivity Push Button	Approximate Resistance for one division
Left (Green)	20 K
Center (Yellow)	200 K
Right (Red)	3 Meg

3.2.2 IDENTIFYING FAULTY CONDUCTORS

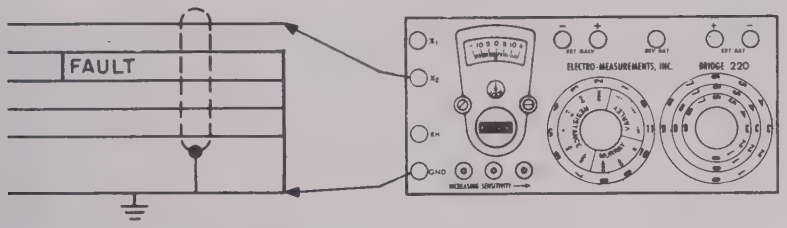
Cable faults resulting from grounds, crosses, and opens can be detected by continuity checks. If the wires are not coded the continuity checks must be made from each end before proceeding with loop tests for locating the fault.

3.2.2.1 TEST FOR GROUND FAULT



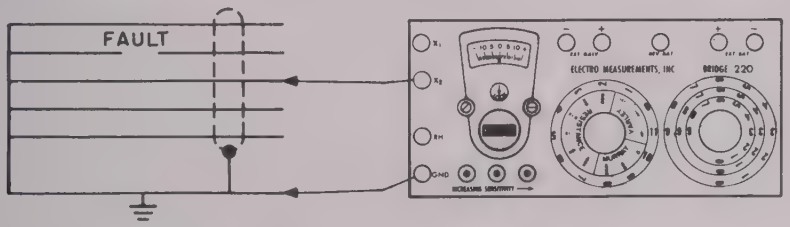
1. Separate all wires at both ends of the cable.
2. Follow the basic instructions for continuity checking (3.2.1).
3. Connect the GND probe to ground (or the cable sheath).
4. Touch the X_2 probe to each wire in turn.
5. GALVANOMETER deflection indicates a wire which is shorted to GND.

3.2.2.2 TEST FOR SHORTED CONDUCTORS



1. Separate all of the wires at the far end.
2. Connect all of the wires to ground (or the cable sheath) at the near end.
3. Follow the basic instructions for continuity checking (3.2.1).
4. Connect the GND probe to ground (or the cable sheath).
5. Disconnect one wire at a time from the ground (or the cable sheath) and touch the X_2 probe to it.
6. GALVANOMETER deflection indicates a wire which is shorted to another wire or to ground.

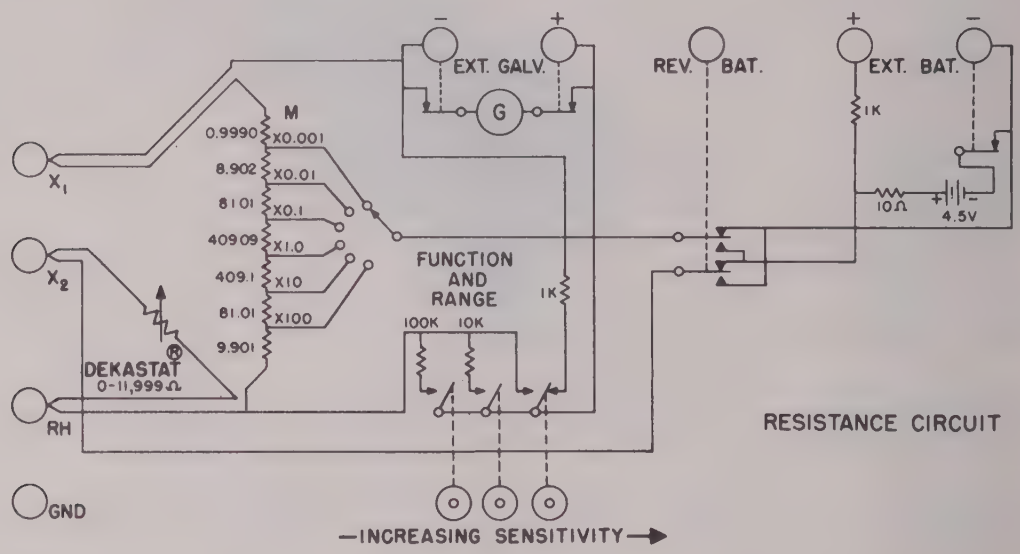
3.2.2.3 TEST FOR OPEN CONDUCTORS



1. Connect all of the wires to ground (or the cable sheath) at the far end.
2. Separate all of the wires at the near end.
3. Follow basic instructions for continuity checking (3.2.1).
4. Connect the GND probe to ground (or the cable sheath).
5. Touch the X_2 probe to each wire in turn.
6. NO GALVANOMETER deflection indicates an open wire.

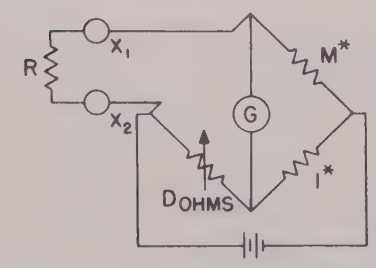
3.3 RESISTANCE MEASUREMENTS

Resistance measurements are made with a Wheatstone Bridge Circuit. The bridge configuration and resistor accuracy permit measurements of 0.1% accuracy for resistors with from 1 ohm to 1.2 meg. On the lowest range each division of the DEKASTAT® represents 1 milliohm so that it is possible to measure resistances below 1 ohm with a resolution of ±1 milliohm when care is taken and lead resistance is subtracted. For resistors above 40K a 45 volt battery should be attached for increased sensitivity.



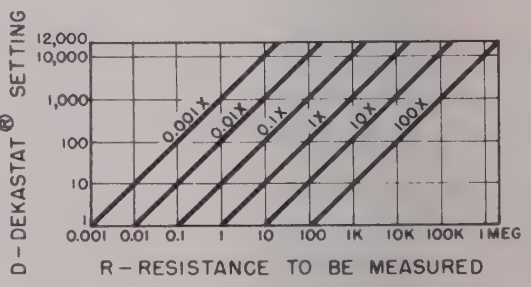
RESISTANCE CIRCUIT

The circuit diagram above shows the complete bridge circuit when the FUNCTION AND RANGE dial is on any of the RESISTANCE ranges. The diagram below has been simplified to emphasize the parts of the circuit which are involved in the balance equation.



SIMPLIFIED RESISTANCE CIRCUIT

R = DM
BALANCE EQUATION



The graph above is a plot of DEKASTAT® setting versus values of resistance for the unknown resistor. There is one curve for each of the six ranges.

*Since only the ratio of these two resistors is involved in the bridge balance equation they have been shown this way for simplicity. The actual values can be found in the complete diagram above.

RESISTANCE MEASUREMENT EQUATIONS

For those who may be interested the following are outline derivations for the equations used with RESISTANCE bridge measurements.

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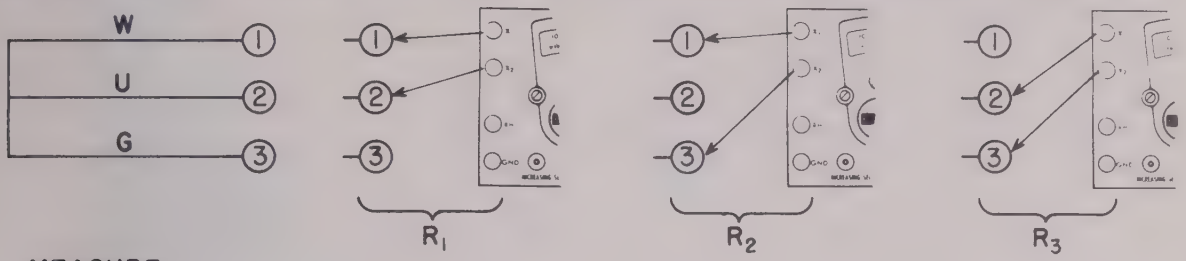
1. CONDUCTOR RESISTANCE OF THREE GOOD WIRES (Y connected resistors)



MEASURE
R_1, R_2, R_3

BY INSPECTION
$R_1 = W+U$ $\qquad R_2 = W+G$ $\qquad R_3 = U+G$

THEN
$W = \frac{1}{2}\left(R_1+R_2-R_3\right)$ $\qquad U = \frac{1}{2}\left(R_1+R_2-R_3\right)$ $\qquad G = \frac{1}{2}\left(R_1+R_2-R_3\right)$

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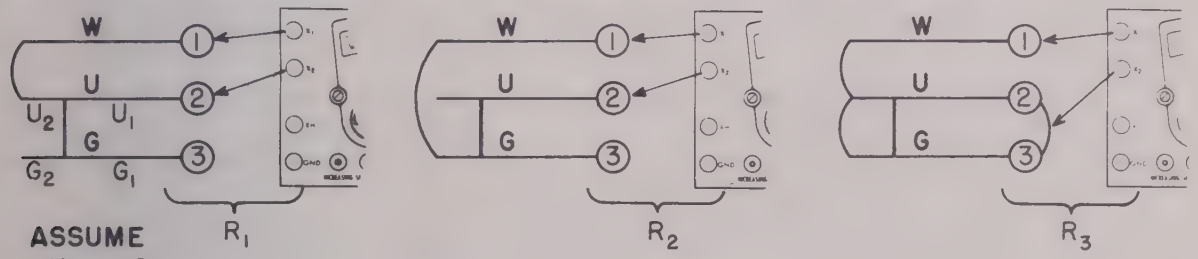
2. CONDUCTOR RESISTANCE OF ONE GOOD AND TWO CROSSED WIRES



ASSUME
$\frac{U_1}{U_2} = \frac{G_1}{G_2}$

MEASURE
R_1, R_2, R_3

BY INSPECTION
$R_1 = W+U$ $\qquad R_2 = W+G$ $\qquad R_3 = W+\frac{UG}{U+G}$

THEN
$W = R_3 - \sqrt{(R_1-R_3)(R_2-R_3)}$ $\qquad U = R_1 - W$ $\qquad G = R_2 - W$

---

3. RESISTANCE LIMITS CHECKING

IF
$R_{MIN} < R < R_{MAX}$

AND IF
$T = R_{MAX} - R_{MIN}$

THEN
$(R_{MEAS}) < R_{MAX}$ Only if $R < R_{MAX}$
$(R_{MEAS}+T) > R_{MAX}$ Only if $R > R_{MIN}$

IF
$R(1+\Delta) = R_{MAX}$
$R(1-\Delta) = R_{MIN}$

THEN
$T = 2\Delta R$

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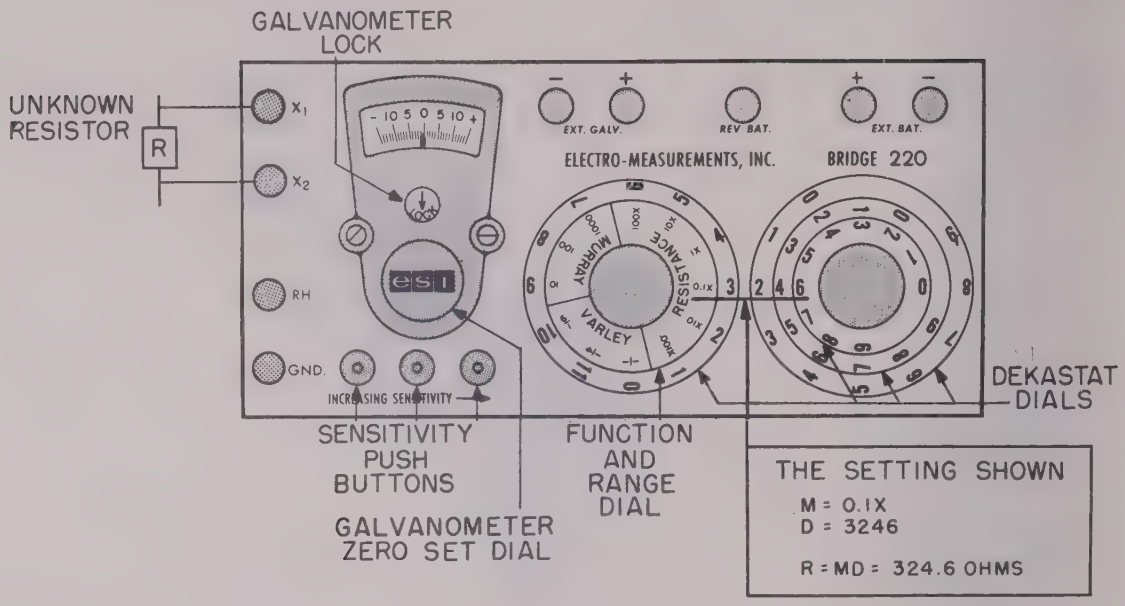


BASIC INSTRUCTIONS

1.	Connect the UNKNOWN RESISTOR between terminals X_1 and X_2.	Be sure that good electrical connection is made to the bridge terminals.
2.	Set the DEKASTAT® dials to read 11,999.	With this setting it is easy to find the correct setting of the FUNCTION AND RANGE dial.
3.	Release the GALVANOMETER LOCK and check the zero position of the pointer.	The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.
4.	Depress the left-hand SENSITIVITY PUSH BUTTON.	This connects the GALVANOMETER, provides the least sensitivity, and connects the battery. The SENSITIVITY BUTTONS may be locked down by pressing, then rotating 1/4 turn.
5.	Set the FUNCTION AND RANGE dial. (M)	Start with the 100X setting and decrease until the GALVANOMETER reading reverses sign, then go back to the last setting before the reversal.

3.3.1 BASIC INSTRUCTION (Cont'd)

6.	Adjust the DEKASTAT® dials for a null. (D)	Begin with the left-hand dial, then work inward on the right-hand dials. Decrease each dial until the GALVANOMETER reading reverses sign, then go back to the last setting before reversal. As the null is approached, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.
7.	The resistance value is the product of the FUNCTION AND RANGE dial reading and the DEKASTAT® reading. $R = MD$	R - The measured value of the UNKNOWN RESISTOR. M - The FUNCTION AND RANGE dial reading. D - The DEKASTAT® reading.
8.	Release all of the SENSITIVITY PUSH BUTTONS.	This turns off the battery and disconnects the GALVANOMETER.
9.	LOCK the GALVANOMETER	This protects the GALVANOMETER from mechanical shock.

3.3.2 HIGH RESISTANCE MEASUREMENTS

The bridge will measure resistances between 0.001 ohm and 1.2 megohm with an accuracy of ±(0.1% + 0.001 ohm). This accuracy can be realized with the internal battery and galvanometer for resistances less than 40 kilohms. For values greater than 40 kilohms a source of higher voltage or a more sensitive galvanometer must be used to realize the rated accuracy. The bridge is designed so that a 45 volt battery connected to the EXT BAT terminals will assure rated accuracy at all settings.

A source of higher voltage may be used but it must not exceed 400 volts and must have a current limiting series resistance of

$$R = \frac{E^2}{4} - 1{,}000$$

ohms where E is the open circuit voltage of the supply. There is a built-in limiting resistor which protects the bridge for external power supplies up to 45 volts.

An external galvanometer may be connected into the circuit through the terminals marked EXT GALV. Connecting the galvanometer to these terminals automatically disconnects the internal galvanometer.

3.3.3 LOW RESISTANCE MEASUREMENTS

On the lowest resistance multiplier position (.001X), the lead resistance in the unknown arm becomes significant. A correction for this resistance can be made as follows:

1. Short the test leads together at the point that they are to be connected to the unknown resistor and measure this "ZERO RESISTANCE".

2. Connect the test leads to the unknown resistor and measure the "RESISTANCE READING".

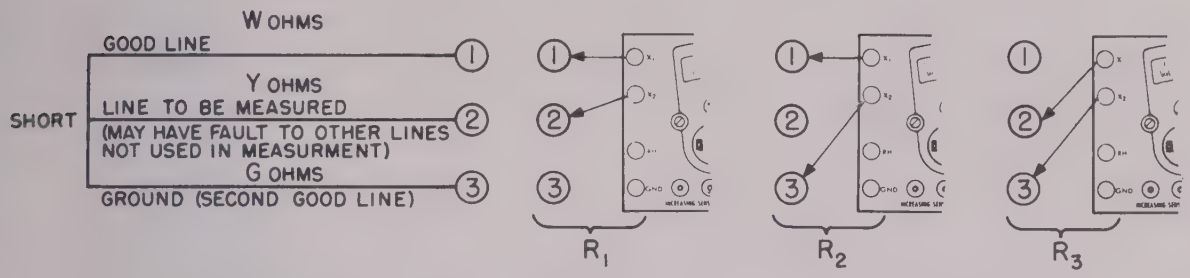
3. The "RESISTANCE VALUE" of the unknown resistor is then the "RESISTANCE READING" minus the "ZERO RESISTANCE".

4. If the unknown resistance is to be connected directly to the terminals, the "ZERO RESISTANCE" reading can be taken by connecting a piece of heavy copper wire between the unknown resistance terminals. (#14 AWG copper wire has a resistance of about 0.00025 ohm/inch.)

Sometimes thermal voltages are generated at connections and these can lead to erroneous balances of the bridge. If this condition is suspected, balance the bridge and then press the battery reversing button. If this results in a different galvanometer reading, change the DEKASTAT® setting until the galvanometer reads the same for both battery polarities. This cancels the effect of the thermal voltages.

3.3.4 CONDUCTOR RESISTANCE

3.3.4.1 For measuring the resistance of each of three lines if there are no faults between the three.



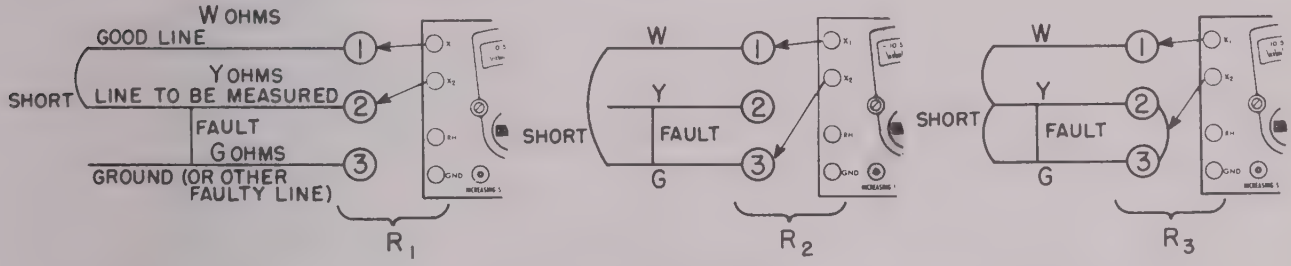
1. Follow the instructions for RESISTANCE measurement (3.3.1).
2. Short the far end of the line to be measured to two good lines, one of which may be ground.
3. Measure R_1 between points (1) and (2).
4. Measure R_2 between points (1) and (3).
5. Measure R_3 between points (2) and (3).
6. Calculate the resistance Y of the line to be measured

$$Y = \frac{1}{2}(R_1 + R_3 - R_2)$$

7. The other line resistances can also be calculated

$$W = \frac{1}{2}(R_1 + R_2 - R_3) \qquad G = \frac{1}{2}(R_2 + R_3 - R_1)$$

3.3.4.2 For measuring the resistance of each of three lines if two of them are crossed.



1. Follow the instructions for RESISTANCE measurement (3.3.1)
2. Short the good line W to the line to be measured Y at the far end.
3. Measure R_1 between these lines.
4. Short the good line W to ground (or the other faulty line) G at the far end.
5. Measure R_2 between these two.
6. Short the line to be measured Y to ground (or the other faulty line) G and to the good line W at the far end.
7. Short Y and G together at the measuring end.
8. Measure R_3 between W and the shorted Y and G.
9. Calculate the resistance of the good line W

$$W = R_3 - \sqrt{(R_1 - R_3)(R_2 - R_3)}$$

10. Calculate the resistance of the line to be measured Y

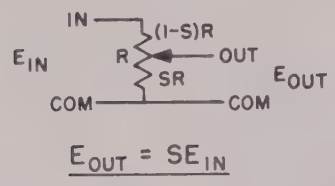
$$Y = R_1 - W$$

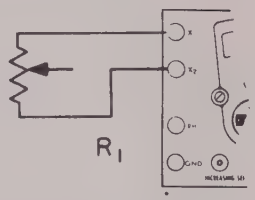
11. The ground (or other faulty line) resistance G can also be calculated

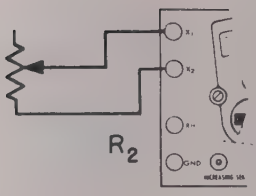
$$G = R_2 - W$$

3.3.5 VOLTAGE DIVIDER CHECKING

3.3.5.1 SIMPLE TAPPED RESISTOR



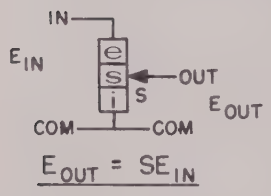




1. Follow the instructions for RESISTANCE measurement (3.3.1).
2. Measure R_1 between the input and common terminals.
3. Measure R_2 between the output and common terminals.
4. Calculate the divider setting S

$$S = \frac{R_2}{R_1}$$

3.3.5.2 For Kelvin Varley and other voltage divider types which may have equivalent resistance in the output lead.



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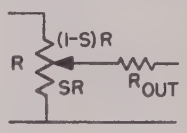
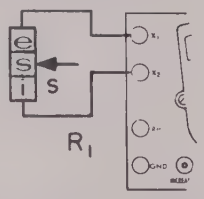
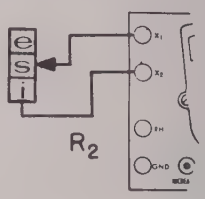
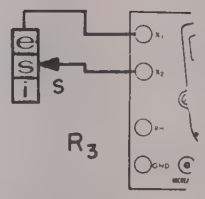








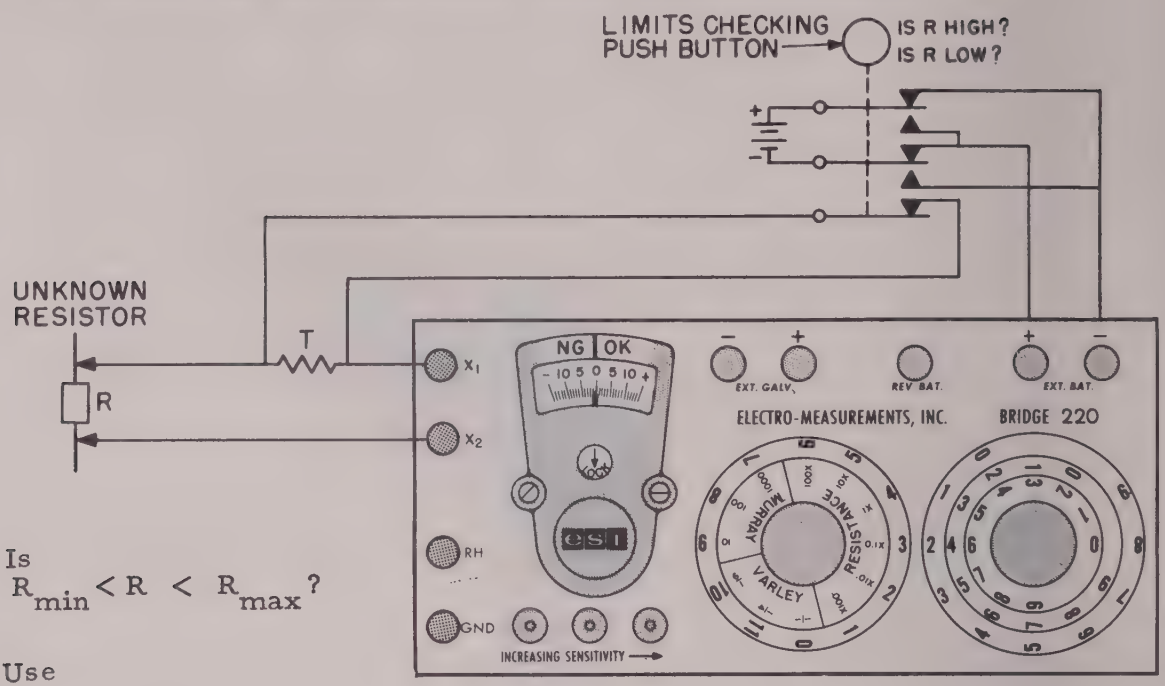
1. Follow the instructions for RESISTANCE measurement (3.3.1).
2. Measure R_1 between the input and common terminals.
3. Measure R_2 between the output and common terminals.
4. Measure R_3 between the input and output terminals.
5. Calculate the divider setting S

$$S = \frac{1}{2} + \frac{R_3 - R_2}{2R_1}$$

3.3.6 RESISTANCE LIMITS CHECKING

the esi *way*

For determing that a resistance value is within tolerance.



Is
$R_{min} < R < R_{max}$?

Use
$T = R_{max} - R_{min}$

3.3.6.1 BASIC INSTRUCTIONS

1.	Set the FUNCTION and RANGE and DEKASTAT® DIALS to read R max	This setting will allow checking both upper and lower limits
2.	Connect the circuit as shown	The battery reversal permits using the same direction of GALVANOMETER deflection for OK with both the upper and lower limit.
3.	Attach the probes to the unknown resistor	This completes the bridge circuit.
4.	Release the GALVANOMETER LOCK and check the zero position of the pointer.	The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.
5.	Depress the left-hand SENSITIVITY PUSH BUTTON.	If no meter deflection is observed, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.
6.	If the GALVANOMETER deflects to the right (+) the resistance value is below R max.	If the GALVANOMETER deflects to the left (-) the resistance value is out of specification by being above R max.

3.3.6.1 BASIC INSTRUCTIONS (Cont'd)

7.	Depress the LIMITS CHECKING push button.	This arranges the bridge for checking the lower limit.
8.	Depress the left-hand SENSITIVITY PUSH BUTTON (while the LIMITS CHECKING push button is depressed.	If no meter deflection is observed, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.
9.	If the GALVANOMETER deflects to the right (+) the resistance value is above R min.	If the GALVANOMETER deflects to the left (-) the resistance value is out of specification by being below R min.

NOTE: If the resistance tolerance is given as $\pm\triangle\%$, the value of T will be $\frac{2\triangle R}{100}$ and R max will be $\left(1 + \frac{\triangle}{100}\right) R$

3.3.6.2 HIGH RESISTANCE CHECKING

When checking high resistances (40 kilohms and greater) a 45 volt battery should be used to assure adequate sensitivity. (See 3.3.2)

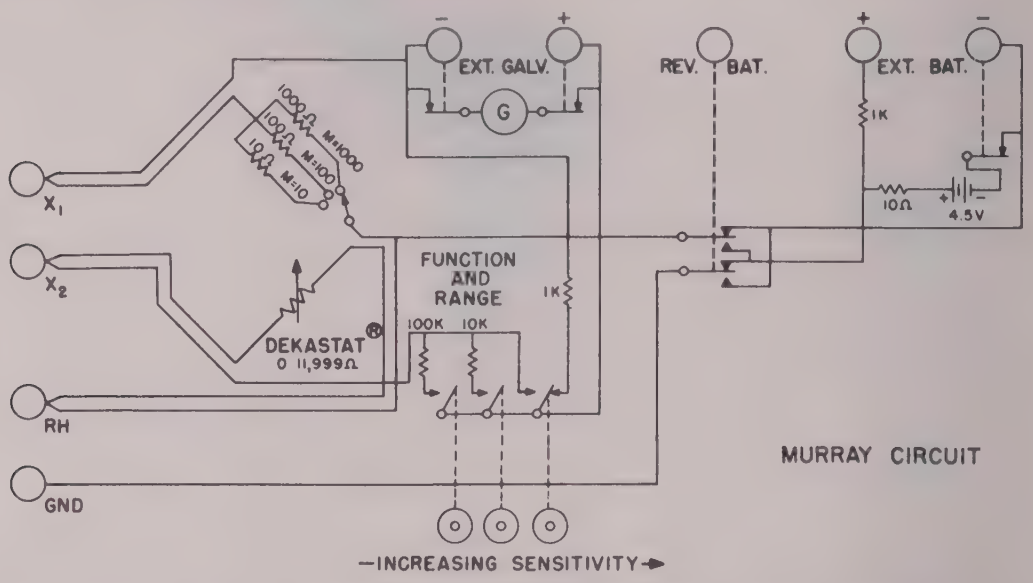
3.3.6.3 LOW RESISTANCE CHECKING

Short the probes together and measure the zero resistance Ro. Then set the dials to read (R max - R min + Ro). Press the LIMITS CHECKING button and adjust T for a null. Set the dials to read (R max + Ro) and proceed from 3.3.6.1 Step 3. (See 3.3.3)

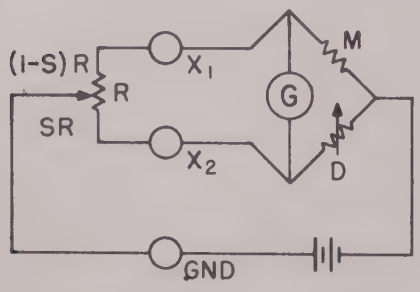
3.4 MURRAY FAULT LOCATING BRIDGE

MURRAY loop measurements are made with a special configuration of a Wheatstone bridge. The measurement results in the ratio S between the resistance from X_2 to the ground tap and the total resistance from X_2 to X_1. Resistance in the lead from GND to the tap point has no effect on the balance setting. With lines of uniform resistance-per-unit-length the measured resistance ratio will be proportional to the comparable distance ratio. Using this assumption, the MURRAY circuit can be used for locating ground faults and line crosses. This circuit can also be used to check a dc voltage divider since the ratio S is analogus to the setting of a resistive divider.

The MURRAY technique will resolve S to better than 0.1% which is accurate enough for very good measurements of short lines.



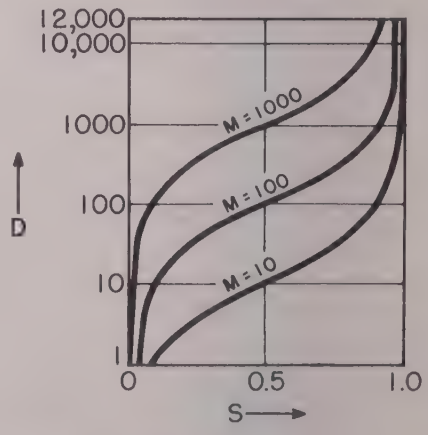
The circuit diagram above shows the complete bridge circuit when the FUNCTION AND RANGE dial is on one of the three MURRAY values. The diagram below has been simplified to emphasize the parts of the circuit which are involved in the balance equation.



SIMPLIFIED DIAGRAM

$$S = \frac{D}{M+D}$$

BALANCE EQUATION

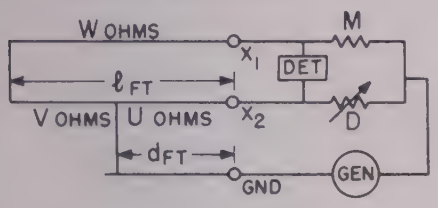


The graph above is a plot of DEKASTAT® setting versus values of the ratio S for the unknown tapped resistor. Separate curves are shown for each of the MURRAY values. Note that the DEKASTAT® setting is determined only by the ratio S and is not affected by the total resistance R.

MURRAY CIRCUIT DISTANCE EQUATIONS

For those who may be interested the following are outline derivations for the equations used with MURRAY bridge measurements.

MURRAY LOOP TEST



ASSUME

$U+V=W$

$\frac{d}{\ell}=\frac{U}{W}$

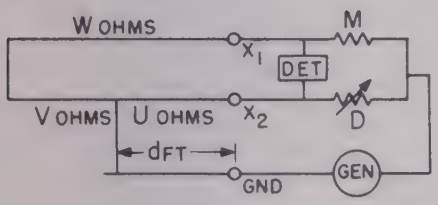
THEN

$d=2\ell\,\frac{D}{M+D}$

BY INSPECTION

$S=\frac{U}{2W}$

ALTERNATE MURRAY LOOP TEST



ASSUME

$BU=d$

MEASURE

$R=U+V+W$

LOOK UP

B ft per ohm

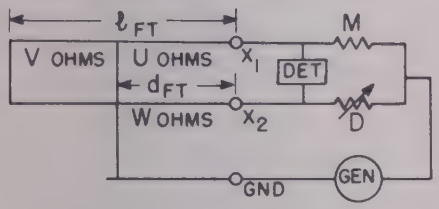
THEN

$d=BR\,\frac{M}{M+D}$

BY INSPECTION

$S=\frac{U}{R}$

MURRAY LOOP CHECK



ASSUME

$U+V=W$

$\frac{d}{\ell}=\frac{U}{W}$

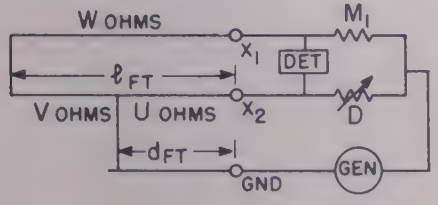
THEN

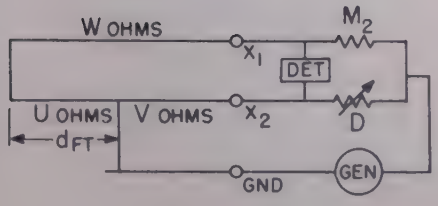
$d=2\ell\,\frac{M}{M+D}$

BY INSPECTION

$S=\frac{W+V}{2W}$

MODIFIED MURRAY LOOP TEST





ASSUME

$\frac{d}{\ell}=\frac{U}{U+V}$

BY INSPECTION

$S_1=\frac{D_1}{M_1+D_1}=\frac{U}{U+V+W}$

$S_2=\frac{D_2}{M_2+D_2}=\frac{V}{U+V+W}$

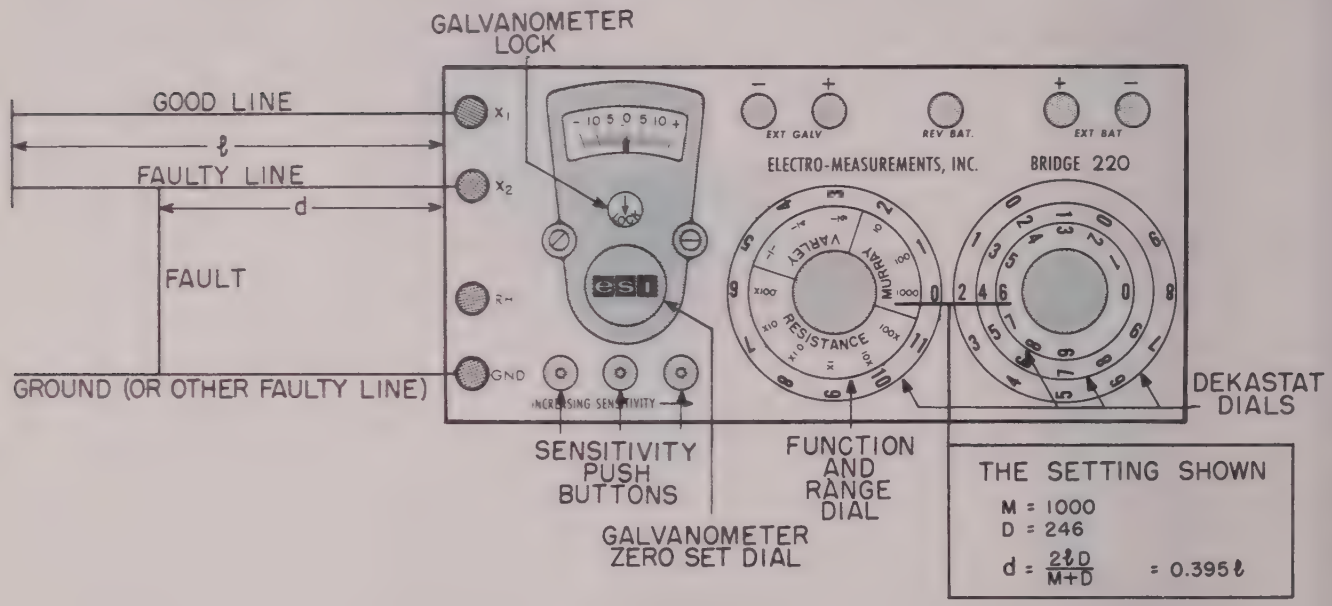
THEN

$d=\ell\,\frac{S_1}{S_1+S_2}$

3.4.1 MURRAY LOOP TEST

the esi way

For short cables that have a good line of the same resistance as the faulty one.



OPERATING INSTRUCTIONS

1. Short the other end of the faulty line to a good line of the same resistance.

   This completes the loop for the measurement.

2. Connect the good line to X_1
   Connect the faulty line to X_2
   Connect the ground (or the other faulty line) to GND.

   This completes the bridge circuit.

3. Determine the length of the faulty line.

   (ℓ)

   This will be needed for determining the distance to the fault. It can be found by measuring the loop resistance if the wire characteristics are known. The loop is already connected to the proper terminals and the ground does not have to be disconnected to measure the loop resistance.

4. Set the DEKASTAT® dials to 0000.

   With this setting it is easy to find the null.

5. Set the FUNCTION AND RANGE dial to MURRAY range 1000

   (M)

   This assures maximum resolution for the measurement.

6. Release the GALVANOMETER LOCK and check the zero position of the pointer.

   The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.

7. Depress the left-hand SENSITIVITY PUSH BUTTON.

   This connects the galvanometer, provides lowest sensitivity, and turns on the battery circuit. The SENSITIVITY BUTTONS may be locked down if desired by pressing, then rotating 1/4 turn.

8. Adjust the DEKASTAT® dials for a null.

   (D)

   Begin with the left-hand dial and work inward on the right-hand dials. As the null is approached, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.

9. Calculate the distance to the fault.

$$d = \frac{\ell 2D}{M + D}$$

   - d - the distance to the fault using any length unit.
   - ℓ - the length of the faulty cable using the same length unit as d.
   - D - the DEKASTAT® setting.
   - M - the MURRAY RANGE setting.

10. Release all of the SENSITIVITY PUSH BUTTONS.

    This turns off the battery and disconnects the GALVANOMETER.

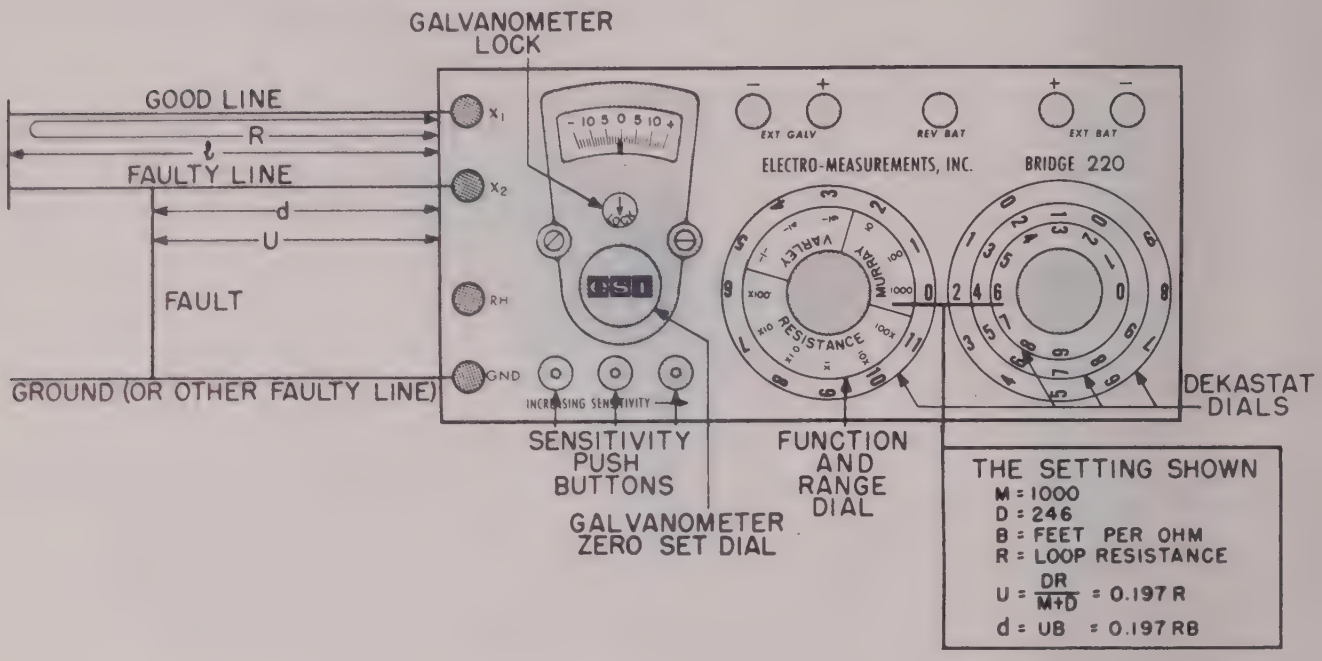
11. LOCK the GALVANOMETER

    This protects the GALVANOMETER from mechanical shock.

3.4.2 ALTERNATE MURRAY LOOP TEST

the esi way

For short cables for which the resistance per unit length of the faulty line is known.



OPERATING INSTRUCTIONS

1.	Short the other end of the faulty line to a good line.	This completes the loop for the measurement.
2.	Connect the good line to X_1 Connect the faulty line to X_2 Connect the ground (or the other faulty line) to GND.	This completes the bridge circuit.
3.	Measure the loop resistance (See 3.1) (R)	This will be needed for determining the distance to the fault. The loop is already connected to the proper terminals and the ground does not have to be disconnected to measure the loop resistance.
4.	Set the DEKASTAT® dials to 0000.	With this setting it is easy to find the null.

3.4.2 ALTERNATE MURRAY LOOP TEST (Cont'd)

5. Set the MULTIPLIER DIAL to MURRAY multiplier 1000 (M = 1000).

   This assures maximum resolution for the measurement.

6. Release the GALVANOMETER LOCK and check the zero position of the pointer.

   The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.

7. Depress the left-hand sensitivity push button.

   This connects the galvanometer, provides lowest sensitivity, and turns on the battery circuit. The sensitivity buttons may be locked down if desired by pressing, then rotating 1/4 turn.

8. Adjust the DEKASTAT® dials for a null.

   Begin with the left-hand dial and work inward on the right-hand dials. As the null is approached increase the sensitivity by using the sensitivity buttons to the right.

9. Calculate the resistance to the fault.

$$U = R \frac{D}{M + D}$$

   U - the resistance to the fault.
   R - the loop resistance
   D - the DEKASTAT® setting.
   M - the Murray MULTIPLIER setting.

10. Calculate the distance to the fault.

$$d = UB$$

   d - the distance to the fault in feet
   U - the resistance to the fault
   B - the number of feet per ohm for the wire gauge of the faulty line, See 7.1

11. Release all of the SENSITIVITY PUSH BUTTONS.

    This turns off the battery and disconnects the GALVANOMETER.

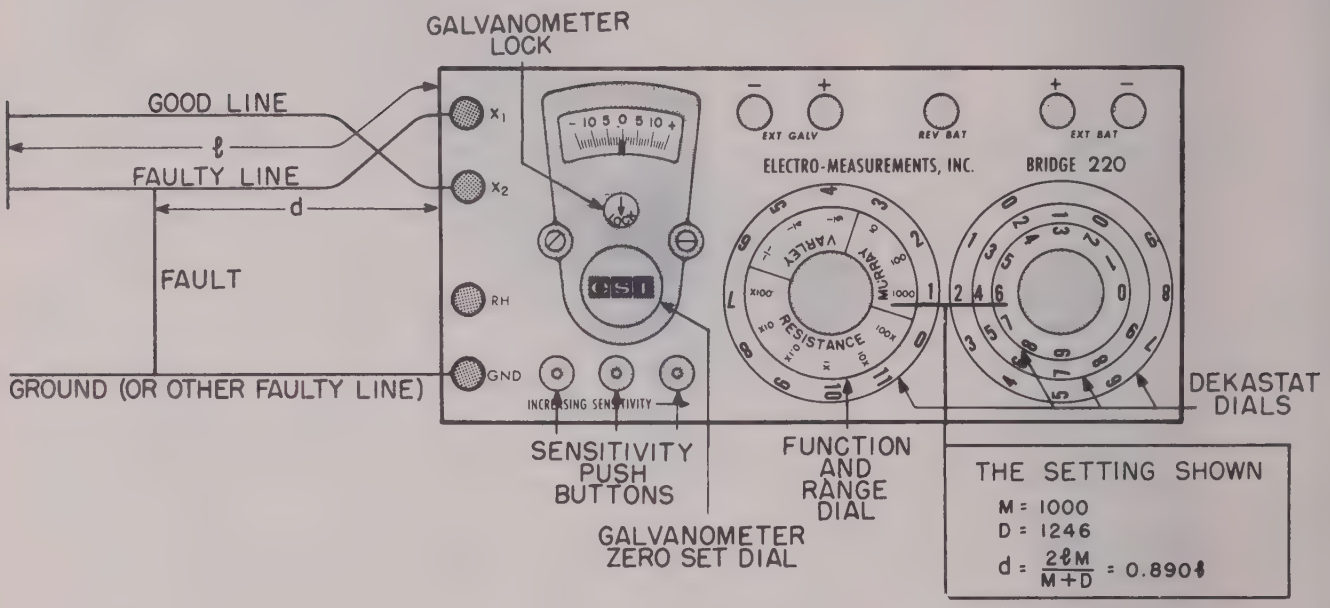
12. LOCK the GALVANOMETER

    This protects the GALVANOMETER from mechanical shock.

3.4.3 MURRAY LOOP CHECK

the esi *way*

For checking the results obtained with the MURRAY LOOP TEST and for increasing resolution. The good line must have the same resistance.



OPERATING INSTRUCTIONS

1.	Short the other end of the faulty line to a good line of the same resistance.	This completes the loop for the measurement.
2.	Connect the faulty line to X_1 Connect the good line to X_2 Connect the ground (or the other faulty line) to GND.	This completes the bridge circuit.
3.	Determine the length of the faulty line. (ℓ)	This will be needed for determining the distance to the fault. It can be found by measuring the loop resistance if the wire characteristics are known. The loop is already connected to the proper terminals and the ground does not have to be disconnected to measure the loop resistance.
4.	Set the DEKASTAT® dials to 0000.	With this setting it is easy to find the null.

5. Set the FUNCTION AND RANGE dial to MURRAY range 1000

   (M)

   This assures maximum resolution for the measurement.

6. Release the GALVANOMETER LOCK and check the zero position of the pointer.

   The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.

7. Depress the left-hand SENSITIVITY PUSH BUTTON.

   This connects the galvanometer, provides lowest sensitivity, and turns on the battery circuit. The SENSITIVITY BUTTONS may be locked down if desired by pressing, then rotating 1/4 turn.

8. Adjust the DEKASTAT® dials for a null.

   (D)

   Begin with the left-hand dial and work inward on the right-hand dials. As the null is approached, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.

9. If a null cannot be reached by the maximum DEKASTAT® setting use the 100 or the 10 FUNCTION AND RANGE setting.

   If d/ℓ is less than 0.154 use M = 100
   If d/ℓ is less than 0.017 use M = 10
   If d/ℓ is less than 0.0017 it cannot be measured with the MURRAY CHECK CIRCUIT

10. Calculate the distance to the fault.

$$d = \ell \frac{2M}{M + D}$$

   - d - the distance to the fault using any length unit.
   - ℓ - the length of the faulty cable using the same length unit as d.
   - D - the DEKASTAT® setting.
   - M - the MURRAY RANGE setting.

11. Release all of the SENSITIVITY PUSH BUTTONS.

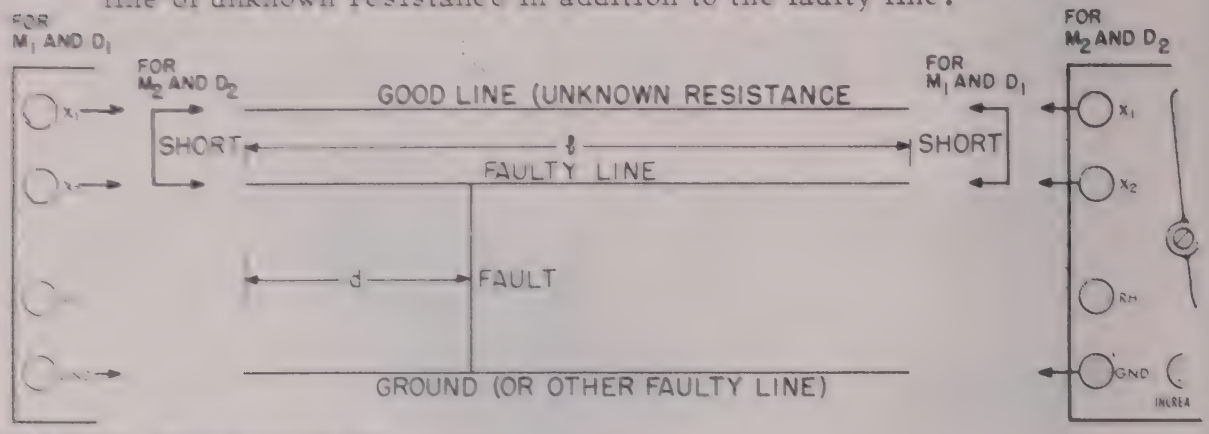
    This turns off the battery and disconnects the GALVANOMETER.

12. LOCK the GALVANOMETER

    This protects the GALVANOMETER from mechanical shock.

3.4.4 MODIFIED MURRAY LOOP TEST

For finding crosses or ground faults in cables that have a good line of unknown resistance in addition to the faulty line.



OPERATING INSTRUCTIONS

1. Make a MURRAY LOOP TEST (3.3.1) from the near end of the line with the far end shorted. Record the FUNCTION and RANGE setting, M_1 and the DEKASTAT® setting, D_1

   (M_1) (D_1)

   It is not necessary that the good line have the same resistance as the faulty one.

2. Make another MURRAY LOOP TEST from the far end of the line with the near end shorted. Record the FUNCTION and RANGE setting, M_2 and the DEKASTAT® setting, D_2

   (M_2) (D_2)

   It is not necessary that the good line have the same resistance as the faulty one.

3. Calculate the distance to the fault

$$d = \frac{d_1}{d_1 - d_2}$$

d - the distance to the fault using any length unit.

d_1, d_2 - see equations

$$d = \ell \frac{d_1}{d_1 + d_2}$$

ℓ the length of the faulty cable in the same length unit as d

where

$$d_1 = \frac{D_1}{D_1 + M_1}$$

D_1 the DEKASTAT® setting with the bridge at the end of the line from which the fault distance is to be calculated

M_1 the multiplier setting obtained with D_1

and

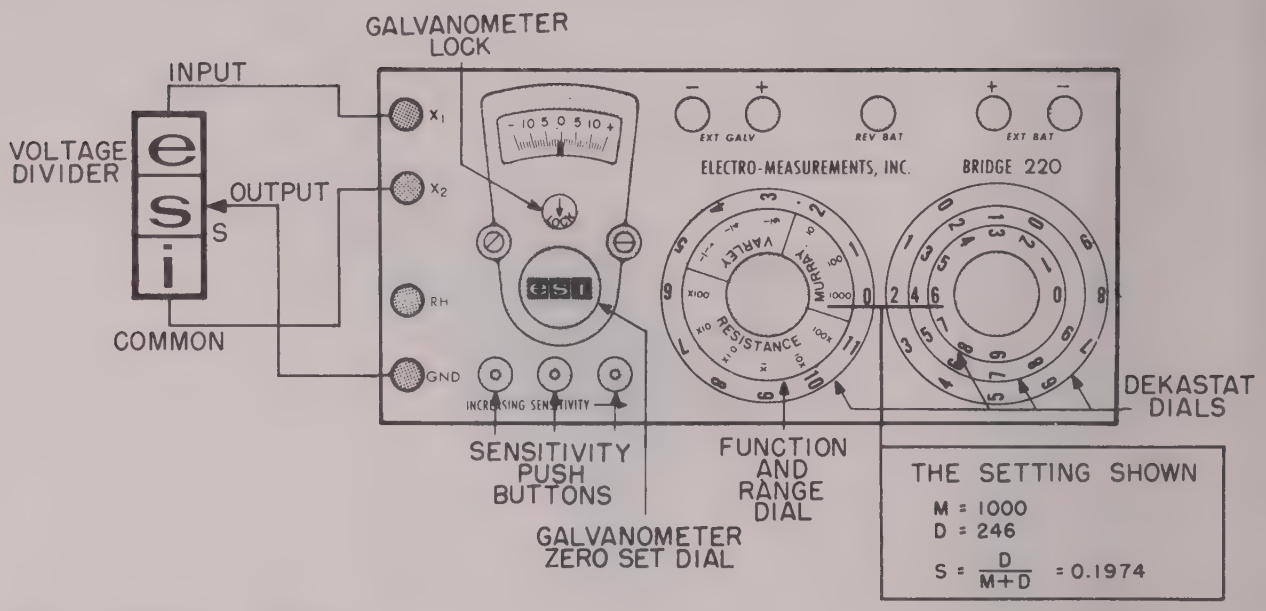
$$d_2 = \frac{D2}{D_2 + M_2}$$

D_2 the DEKASTAT® setting with the bridge at the other end of the line

M_2 the Multiplier setting obtained with D_2

3.4.5 VOLTAGE DIVIDER CHECKING

the esi way



BASIC INSTRUCTIONS

1.	Connect the voltage divider INPUT lead to X_1. Connect the COMMON lead to X_2. Connect the OUTPUT lead to GND.	This completes the bridge circuit.
2.	Set the voltage divider to the desired setting.	Any setting between 0 and 0.923 (11,999/12,999) can be checked.
3.	Set the FUNCTION AND RANGE dial to MURRAY range 1000 (M)	This assures maximum resolution for the measurement.
4.	Release the GALVANOMETER LOCK and check the zero position of the pointer.	The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.
5.	Depress the left-hand SENSITIVITY PUSH BUTTON.	This connects the galvanometer, provides lowest sensitivity, and turns on the battery circuit. The SENSITIVITY BUTTONS may be locked down if desired by pressing, then rotating 1/4 turn.
6.	Adjust the DEKASTAT® dials for a null. (D)	Begin with the left-hand dial and work inward on the right-hand dials. As the null is approached, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.

3.4.6 CHECKING VOLTAGE DIVIDER DECADES

For checking the linearity of voltage divider decades the following table can be used. Measurements at these settings will check all of the resistors and switch positions for the first three decades. Follow the BASIC INSTRUCTIONS, 3.4.5, through step 6. Then set the DEKASTAT® to the value indicated in the table. If the minimum galvanometer deflection occurs at the DEKASTAT® setting indicated by the chart the divider linearity is better than 0.05%.

DIVIDER SETTING	BRIDGE DEKASTAT® SETTING
.000	0000
.100	0111
.200	0250
.300	0429
.400	0667
.500	1000
.600	1500
.700	2334
.800	4000
.900	9000

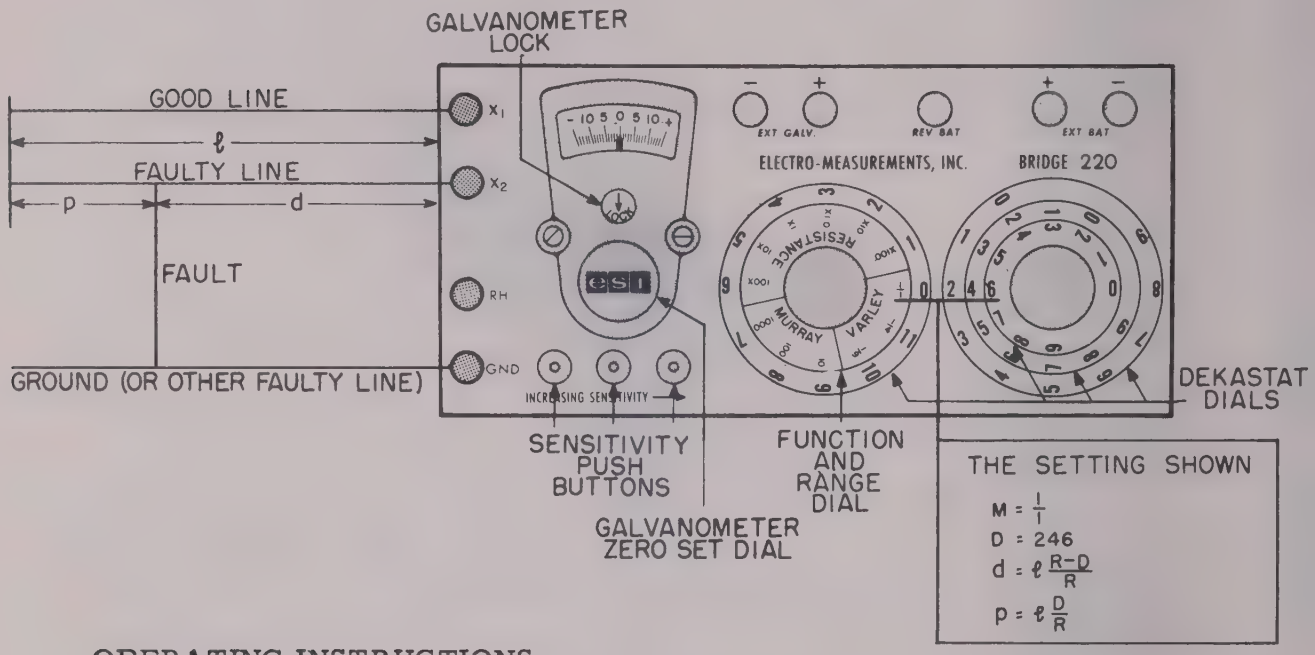
DIVIDER SETTING	BRIDGE DEKASTAT® SETTING
.000	0000
.010	0010
.020	0020
.030	0031
.040	0042
.050	0053
.060	0064
.070	0075
.080	0087
.090	0099

DIVIDER SETTING	BRIDGE DEKASTAT® SETTING
.000	0000
.001	0001
.002	0002
.003	0003
.004	0004
.005	0005
.006	0006
.007	0007
.008	0008
.009	0009

3.5.1 SIMPLE VARLEY LOOP TEST

the esi way

For long cables that have a good line of the same resistance as the faulty one.



OPERATING INSTRUCTIONS

1.	Short the other end of the faulty line to a good line of the same resistance.	This completes the loop for the measurement.
2.	Connect the good line to X_1 Connect the faulty line to X_2 Connect the ground (or the other faulty line) to GND.	This completes the bridge circuit.
3.	Determine the length of the faulty line. (ℓ)	This will be needed for determining the distance to the fault. It can be found by measuring the loop resistance if the wire characteristics are known.
4.	Measure the loop resistance (See 3.1) (R)	This will be needed for determining the distance to the fault. The loop is already connected to the proper terminals and the ground does not have to be disconnected to measure the loop resistance.
5.	Set the DEKASTAT® dials to 0000.	With this setting it is easy to find the null.

6. Set the FUNCTION AND RANGE dial to VARLEY 1/1

   (M)

   This insures that any fault position can be determined if $R < 11,999$ ohms.

7. Release the GALVANOMETER LOCK and check the zero position of the pointer.

   The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.

8. Depress the left-hand SENSITIVITY PUSH BUTTON.

   This connects the galvanometer, provides lowest sensitivity, and turns on the battery circuit. The SENSITIVITY BUTTONS may be locked down if desired by pressing, then rotating 1/4 turn.

9. Adjust the DEKASTAT® dials for a null.

   (D)

   Begin with the left-hand dial and work inward on the right-hand dials. As the null is approached, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.

10. Calculate the distance to the fault.

$$d = \ell \frac{R - D}{R}$$

$$p = \ell \frac{D}{R}$$

- d - the distance to the fault using any length unit.
- p - the distance from the fault to the other end, using the same length unit as d.
- ℓ - the length of the faulty cable using the same length unit as d.
- D - the DEKASTAT® setting.
- R - the loop resistance

11. Release all of the SENSITIVITY PUSH BUTTONS.

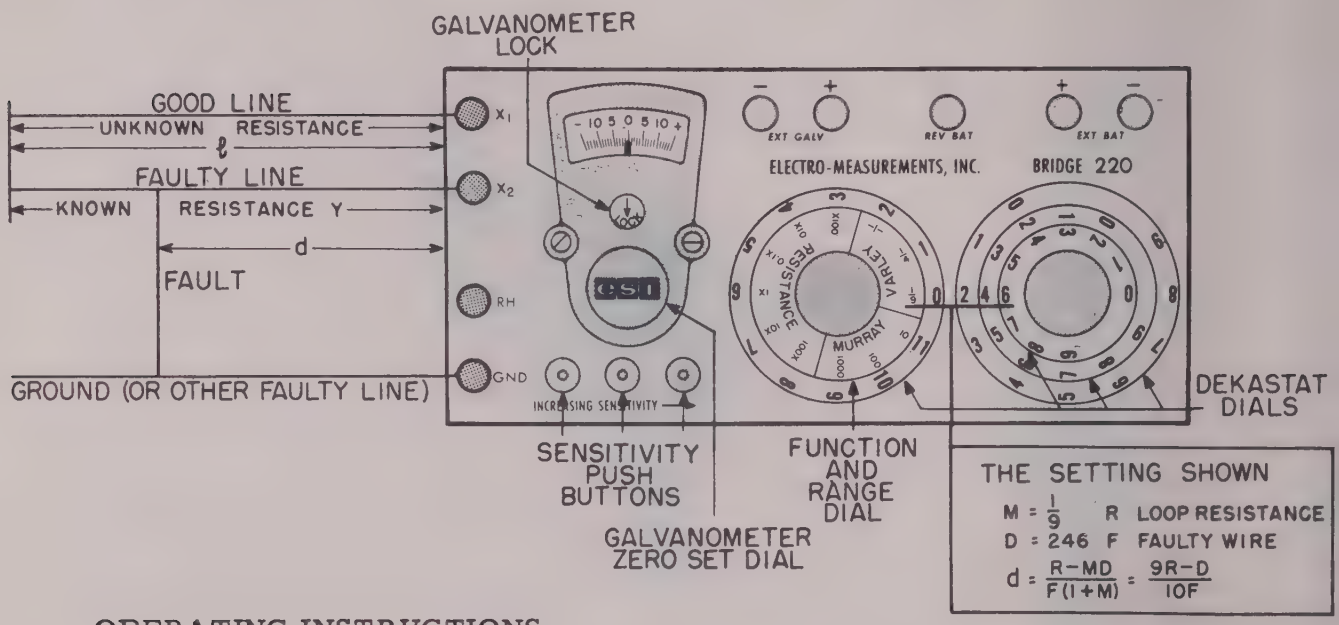
    This turns off the battery and disconnects the GALVANOMETER.

12. LOCK the GALVANOMETER

    This protects the GALVANOMETER from mechanical shock.

the esi way

For long cables if the resistance of the faulty wire is known.



OPERATING INSTRUCTIONS

1.	Short the other end of the faulty line to a good line.	This completes the loop for the measurement.
2.	Connect the good line to X_1 Connect the faulty line to X_2 Connect the ground (or the other faulty line) to GND.	This completes the bridge circuit.
3.	Determine the length of the faulty line. (ℓ)	This will be needed for determining the distance to the fault. It can be found by measuring the loop resistance if the wire characteristics are known.
4.	Measure the loop resistance (See 3.1) (R)	This will be needed for determining the distance to the fault. The loop is already connected to the proper terminals and the ground does not have to be disconnected to measure the loop resistance.
5.	Set the DEKASTAT® dials to 0000.	With this setting it is easy to find the null.
6.	Set the FUNCTION AND RANGE dial to VARLEY range 1/9. (M)	This assures maximum resolution for the measurement.

7. Release the GALVANOMETER LOCK and check the zero position of the pointer.

The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.

8. Depress the left-hand SENSITIVITY PUSH BUTTON.

This connects the galvanometer, provides lowest sensitivity, and turns on the battery circuit. The SENSITIVITY BUTTONS may be locked down if desired by pressing, then rotating 1/4 turn.

9. Adjust the DEKASTAT® dials for a null.

(D)

Begin with the left-hand dial and work inward on the right-hand dials. As the null is approached, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.

10. If a null cannot be reached by the maximum DEKASTAT® setting use the 1/4 or 1/1 FUNCTION and RANGE dial setting.

The 1/4 and 1/1 settings permit finding faults which are near the bridge end of the line.

If $R>(2D)/3$ there will be a gap of unattainable d values between the 1/4 and the 1/1 settings.

If $R>D$ there will be a gap between the 1/9 and the 1/4 setings.

11. If a null cannot be reached by the zero DEKASTAT® setting, another type of bridge circuit must be used.

The zero DEKASTAT® setting with the 1/9 FUNCTION AND RANGE setting provides the maximum distance at which a fault can be found.

12. Calculate the distance to the fault.

FUNCTION AND RANGE SETTING	DISTANCE EQUATION
1/9	$d = \frac{\ell}{10Y}(9R - D)$
1/4	$d = \frac{\ell}{5Y}(4R - D)$
1/1	$d = \frac{\ell}{2Y}(R - D)$

d - the distance to the fault using any length unit.

ℓ - the length of the faulty cable using the same length unit as d.

D - the DEKASTAT® setting.

R - the loop resistance

Y - the resistance of the faulty line.

13. Release all GALVANOMETER SENSITIVITY push buttons.

This turns off the battery and disconnects the galvanometer.

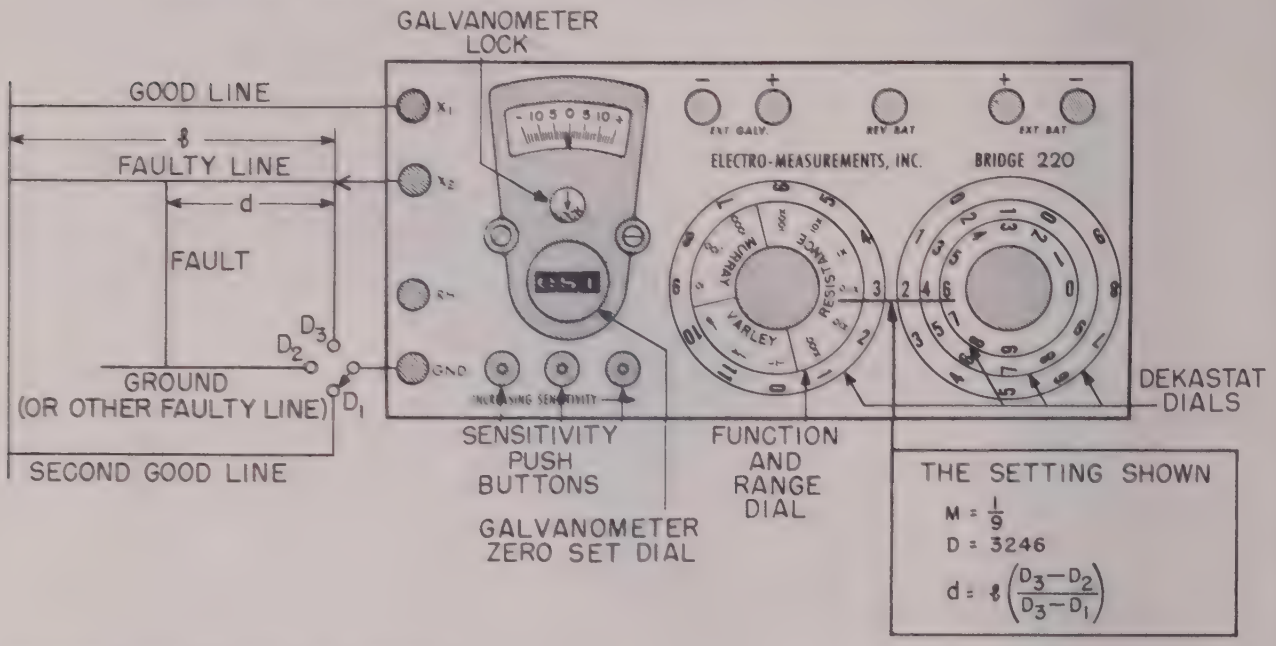
14. LOCK the galvanometer.

This protects the galvanometer from mechanical shock.

3.5.3 THREE VARLEY LOOP TEST

the esi *way*

For use with a faulty line of known length and two good lines of unknown characteristics.



OPERATING INSTRUCTIONS

1.	Short the other end of the faulty line to two good lines.	This completes the loop for the measurement.
2.	Connect the good line to X_1 Connect the faulty line to X_2 Connect the second good line to GND.	This completes the bridge circuit.
3.	Determine the length of the faulty line. (ℓ)	This will be needed for determining the distance to the fault. It can be found by measuring the loop resistance if the wire characteristics are known. The loop is already connected to the proper terminals and the ground does not have to be disconnected to measure the loop resistance.
4.	Set the DEKASTAT® dials to 0000.	With this setting it is easy to find the null.
5.	Set the FUNCTION AND RANGE dial to VARLEY range indicated by the loop resistance.	This assures maximum resolution for the measurement.

6. Release the GALVANOMETER LOCK and check the zero position of the pointer.	The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.
7. Depress the left-hand SENSITIVITY PUSH BUTTON.	This connects the galvanometer, provides lowest sensitivity, and turns on the battery circuit. The SENSITIVITY BUTTONS may be locked down if desired by pressing, then rotating 1/4 turn.
8. Adjust the DEKASTAT® dials for a null. (D_1)	Begin with the left-hand dial and work inward on the right-hand dials. As the null is approached, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.
9. If a null cannot be reached by the maximum DEKASTAT® setting use the 1/4 or 1/1 FUNCTION AND RANGE dial setting.	The 1/4 and 1/1 settings permit finding faults which are near the bridge end of the line. If R>(2D)/3 there will be a gap of unattainable d values between the 1/4 and the 1/1 settings. If R >D there will be a gap between the 1/9 and the 1/4 settings.
10. If a balance cannot be reached even with the 1/1 setting, try the MODIFIED THREE VARLEY LOOP TEST 3.5.4	If the loop resistance is greater than 12k and the faulty line has higher resistance than the good line this may be necessary.
11. Disconnect the second good line from the GND terminal and replace it with the ground (or other faulty wire).	This connects the bridge for measuring D_2.
12. Repeat steps 7 and 8 and record the DEKASTAT® setting. (D_2)	All three D readings must be made with the same VARLEY setting.
13. Disconnect the ground (or other faulty wire) from the GND terminal and replace it with a lead to the near end of the faulty line, which is connected to X_2.	This connects the bridge for measuring D_3. NOTE: the resistance of the lead between this connection to the faulty line and the terminal X_2 will not be included in the measurement.

(Over)

14. Repeat steps 8 and 9 and record the DEKASTAT® setting.

    (D_3)

    All three D readings must be made with the same VARLEY setting.

15. Calculate the distance to the fault.

$$d = \ell \frac{D_3 - D_2}{D_3 - D_1}$$

- d - the distance to the fault using any length unit.
- ℓ - the length of the faulty cable using the same length unit as d.
- D_1 - the DEKASTAT® setting with the second good line connected to GND.
- D_2 - the DEKASTAT® setting with the ground (another faulty line) connected to GND.
- D_3 - the DEKASTAT® setting with the lead from the near end of the faulty line connected to GND.

16. Release all of the SENSITIVITY PUSH BUTTONS.

    This turns off the battery and disconnects the GALVANOMETER.

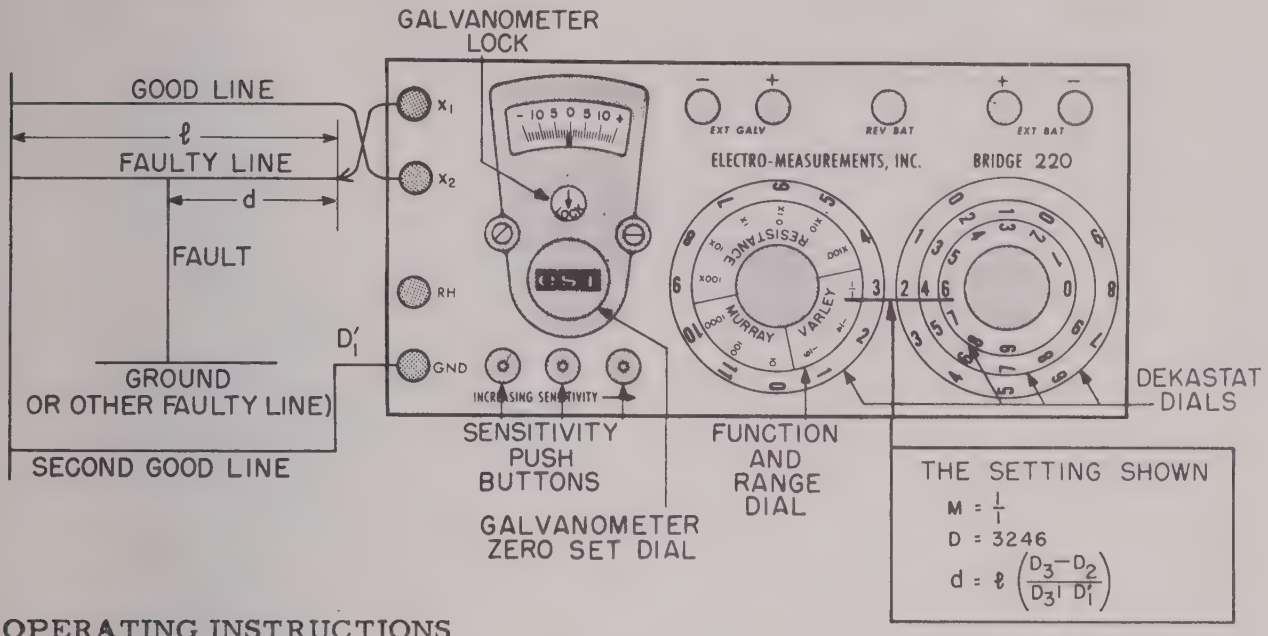
17. LOCK the GALVANOMETER

    This protects the GALVANOMETER from mechanical shock.

3.5.4 MODIFIED THREE VARLEY LOOP TEST

the esi *way*

For use when the loop resistance is greater than 12k and a balance cannot be obtained in 9 of 3.5.3.



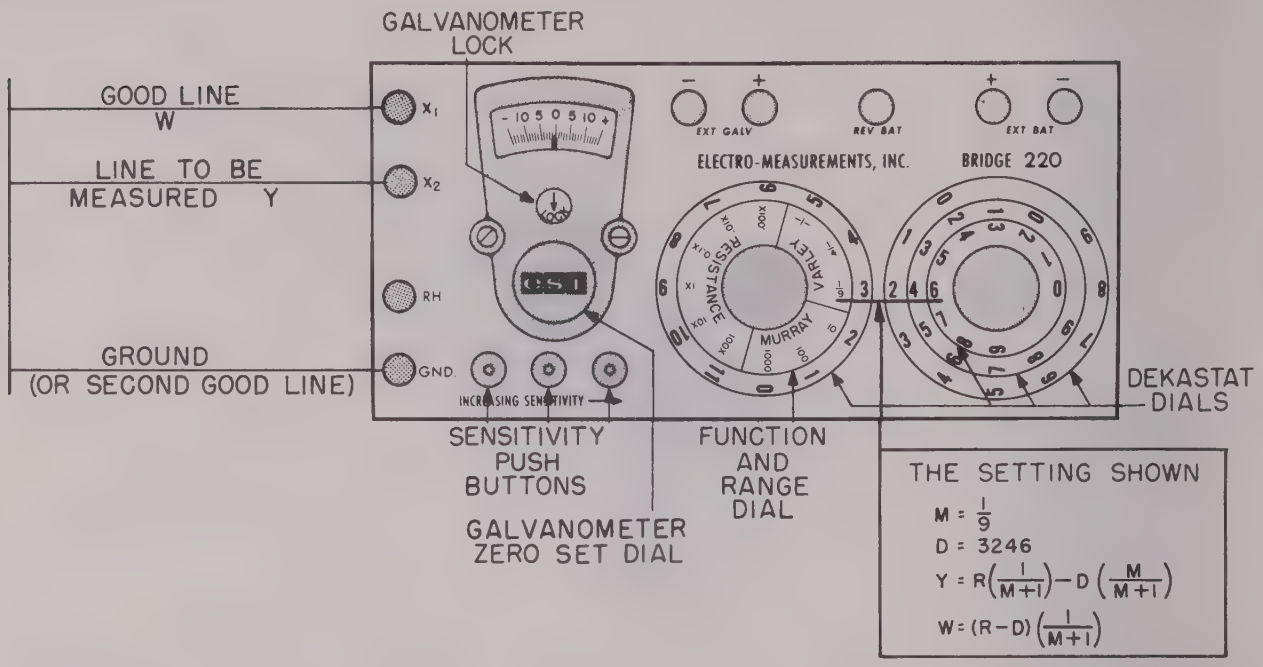
OPERATING INSTRUCTIONS

1.	Short the other end of the faulty line to two good lines.	This completes the loop for the measurement.
2.	Connect the faulty line to X_1. Connect the good line to X_2. Connect the second good line to GND.	This completes the bridge circuit for measuring D_1' only.
3.	Set the FUNCTION AND RANGE dial to VARLEY range 1/1.	This is the only range for which this test is practical.
4.	Follow 3.5.3 steps 4 through 8 except 5 and 6. Record the DEKASTAT® setting. (D_1')	This measures D_1' .
5.	Connect the good line to X_1. Connect the faulty line to X_2. Connect the ground (or the other faulty line) to GND.	This completes the bridge circuit for measuring D_2.
6.	Follow 3.5.3 steps 12 through 14.	This measures D_2 and D_3.
7.	Calculate the distance to the fault $d = \ell \frac{D_3 - D_2}{D_3 + D_1'}$	See 3.5.3 step 15. D_1' - The DEKASTAT® setting with the second good line connected to GND and the good and faulty lines reversed.
8.	Follow 3.5.3 steps 16 and 17.	

3.5.5 CONDUCTOR RESISTANCE BY THE VARLEY METHOD

the esi *way*

For finding the resistance of a line if another good line is available.



OPERATING INSTRUCTIONS

1.	Short the other end of the line to be measured to a good line of the same resistance and to ground (or a second good line).	This completes the loop for the measurement.
2.	Connect the good line to X_1. Connect the line to be measured to X_2. Connect the ground (or the other good line) to GND.	This completes the bridge circuit.
3.	Measure the loop resistance. (See 3.1) (R)	This will be needed for determining the distance to the fault. The loop is already connected to the proper terminals and the ground does not have to be disconnected to measure the loop resistance.
4.	Set the DEKASTAT® dials to 0000.	With this setting it is easy to find the null.
5.	Set the FUNCTION AND RANGE dial to VARLEY range 1/9. (M)	This assures maximum resolution for the measurement.
6.	Release the GALVANOMETER LOCK and check the zero position of the pointer.	The zero position may be adjusted by the GALVANOMETER ZERO SET dial. The screws in the sides of the dial may need adjustment.

7. Depress the left-hand SENSITIVITY PUSH BUTTON.

This connects the galvanometer, provides lowest sensitivity, and turns on the battery circuit. The SENSITIVITY BUTTONS may be locked down if desired by pressing, then rotating 1/4 turn.

8. Adjust the DEKASTAT® dials for a null.

(D)

Begin with the left-hand dial and work inward on the right-hand dials. As the null is approached, increase the sensitivity by using the SENSITIVITY BUTTONS to the right.

9. If a null cannot be reached by the maximum DEKASTAT® setting, try the 1/4 setting then the 1/1 setting. If a null still cannot be reached, interchange the good line and the line to be measured, repeat the Operating Instructions and solve the equation for W.

Each range setting covers a certain range of loop resistances and line ratios Y:W and the proper range must be found by trial and error.

10. Calculate the line resistance.

M	Y	W
1/9	$Y = \frac{1}{10}(9R - D)$	$W = \frac{1}{10}(R + D)$
1/4	$Y = \frac{1}{5}(4R - D)$	$W = \frac{1}{5}(R + D)$
1/1	$Y = \frac{1}{2}(R - D)$	$W = \frac{1}{2}(R + D)$

Y - the resistance of the line to be measured.

W - the resistance of the good line.

R - the loop resistance $R = Y + W$.

D - the DEKASTAT® setting.

M - the FUNCTION AND RANGE dial setting.

11. Release all of the SENSITIVITY PUSH BUTTONS.

This turns off the battery and disconnects the GALVANOMETER.

12. LOCK the GALVANOMETER.

This protects the GALVANOMETER from mechanical shock.

3.6 TO USE AN EXTERNAL BATTERY OR GENERATOR

A 45 volt battery may be safely connected directly to the external battery terminals of the bridge.

An external voltage source of 400 volts or less may be used with the bridge provided the proper precautions are taken. A protective resistance must be in series with the applied voltage. This resistance limits the power available to the bridge to one watt. All of the bridge components, even the GALVANOMETER at the maximum sensitivity setting, can dissipate this power safely. The value of this resistance can be calculated from the following formula or obtained from the table below.

$$R = \left(\frac{E^2}{4} - 1{,}000\right) \text{ ohms}$$

where,

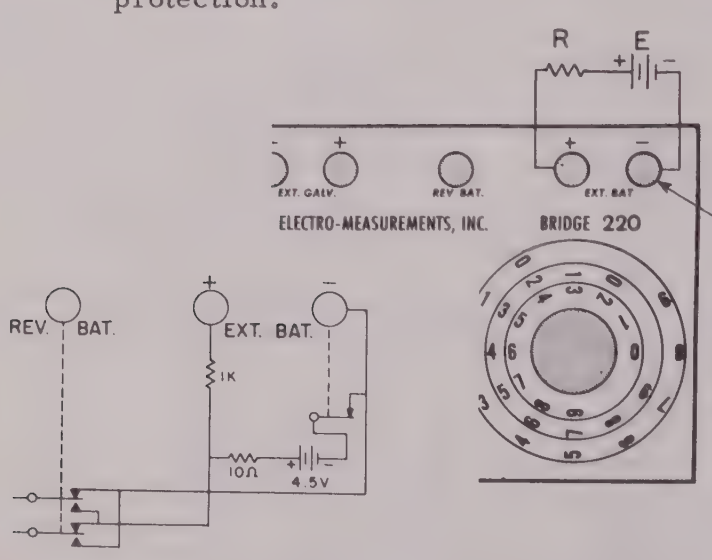
R is the value of the protective resistance

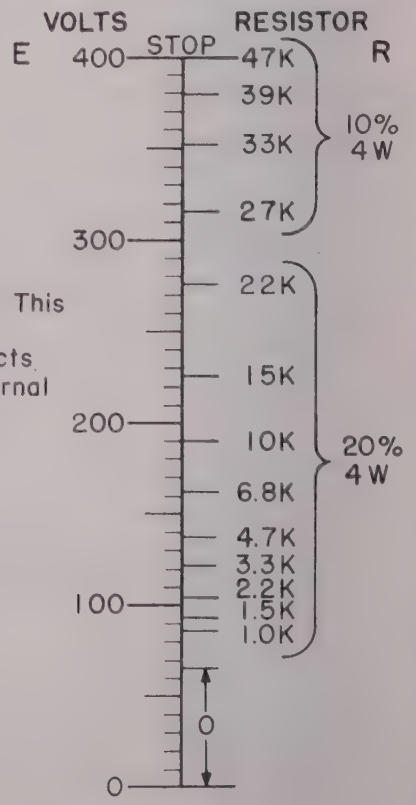
E is the open circuit voltage of the external supply

The protective resistor should have a power rating of 4 watts.

A 1 kilohm resistor is provided internally for protecting the bridge when voltages of 45 volts or less are used. A 10 ohm resistor protects the bridge when the 4.5 volt internal battery is being used.

The accompanying chart gives the maximum voltage to which the indicated resistors, or commercial tolerance (20%), will provide protection.



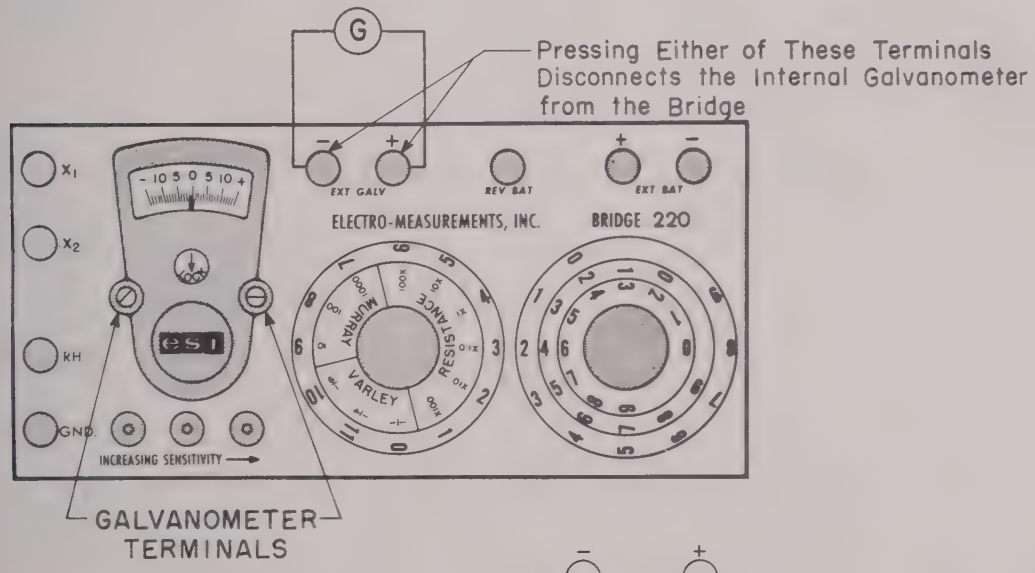


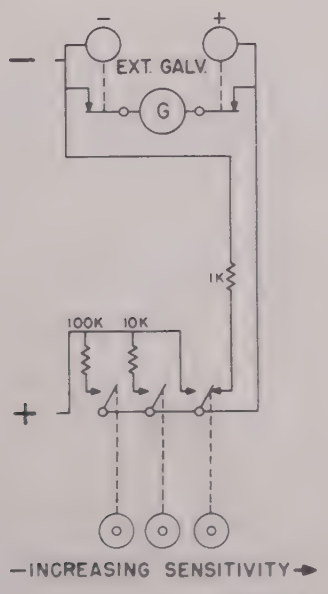
3.7 TO USE AN EXTERNAL GALVANOMETER

An external galvanometer can be used with the bridge for increasing the sensitivity of the measurements.

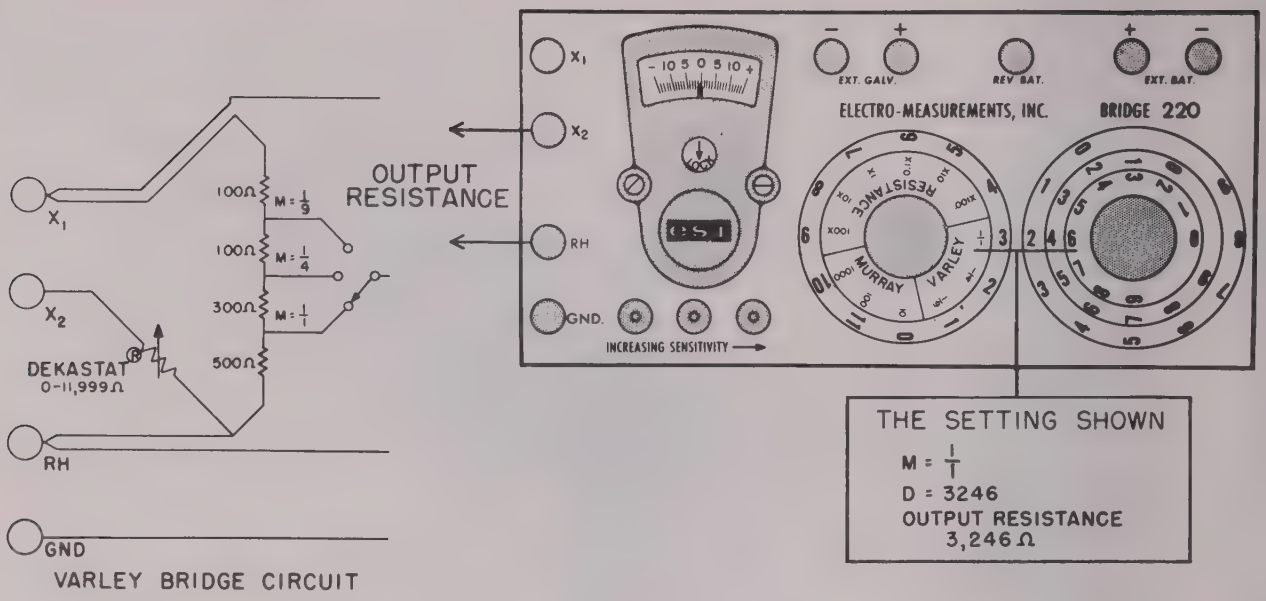
The internal galvanometer has a sensitivity of about one microampere per division and is designed for a critical damping resistance of about 1000 ohms. It can be used separately by connecting to the two mounting screws and pressing one of the external galvanometer terminals to disconnect it from the bridge circuit.

To be effective, an external galvanometer should have a greater sensitivity than one microampere per division and operate with a critical damping resistance between 500 and 2000 ohms. A sensitivity of 0.03 microamperes per division should prove adequate for all bridge uses.





TO USE THE DEKASTAT® AS A VARIABLE RESISTOR



OPERATING INSTRUCTIONS

1. Connect the output leads to terminals X_2 and RH.

   The DEKASTAT® is connected between RH and X_2 for all FUNCTION AND RANGE dial settings. The BATTERY and GALVANOMETER are disconnected unless a sensitivity button is depressed.

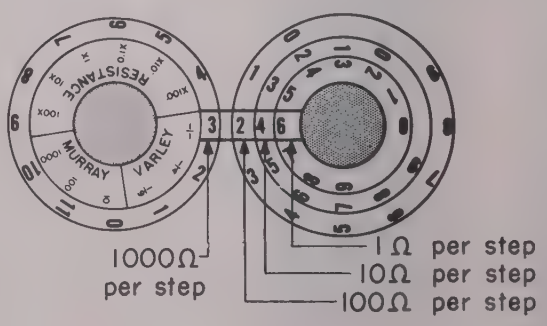
2. Set the FUNCTION AND RANGE dial to VARLEY 1/1.

   This, or either of the other VARLEY settings, disconnects the X_2 terminal of the DEKASTAT® from the bridge for added protection.

3. <u>DO NOT EXCEED THE CURRENT RATING OF THE DEKASTAT®.</u>

   First Decade (1000Ω steps) 22ma
   Second Decade (100Ω steps) 70ma
   Third Decade (10Ω steps) 220ma
   Fourth Decade (1Ω steps) 700ma

4. Set the desired resistance with the DEKADIAL®.



4. SPECIFICATIONS:

Resistance Bridge Range:

0 to 1.2 megohms	0.001 ohm per dial division on lowest range.

- - - - - -

Resistance Bridge Accuracy:

±(0.1% + 0.001 ohm)*	The short-circuit resistance is less than 2 milliohms

- - - - - -

Decade Resistance Dials:

The four-dial DEKADIAL® assembly may be set to any whole-number reading between 0 to 11,999 ohms	The DEKADIAL® assembly controls a DEKASTAT® four-decade resistor covering a range from 0 to 11,999 ohms in one ohm steps. This unit can be used as an independent resistance box if desired. Its accuracy is ±(0.05% plus 0.007 ohm) after correction for a zero resistance of approximately 0.020 ohm.

- - - - - -

Function and Range Dials:

Resistance multipliers: 100X, 10X, 1X, 0.1X, .01X, .001X	Resistance multipliers, Murray resistances and Varley ratios are accurate to ±0.05%.
Varley ratios: 1/1, 1/4, 1/9	
Murray resistances: 1000, 100, 10	

- - - - - -

Battery:

Three standard "D" cells contained within the bridge provide a voltage of 4-1/2 volts. Where a higher voltage is needed, an external battery may be connected to terminals provided on the panel of the bridge.	Whenever power is supplied to the bridge from an external source, it must be limited so it will never exceed one watt. A built-in series limiting resistor provides this protection for external supplies up to 45 volts. Up to 400 volts may be used, but above 45 volts additional series resistance must be provided.

*For high resistance values a 45 volt external battery is necessary for sufficient sensitivity to take advantage of the bridge's accuracy. For low resistances the zero resistance of the bridge and leads must be subtracted for accurate measurements.

4. SPECIFICATIONS (Cont'd)

Galvanometer:

The self-contained pointer type galvanometer has a sensitivity better than 1 microampere per dial division, an internal resistance of 250 ohms and an external damping resistance of 1000 ohms.

An external galvanometer may be used if desired. Terminals are provided on the front panel for external galvanometer connection.

- - - - - -

Sensitivity Control Buttons:

Three control buttons are provided for the selection of galvanometer sensitivity. Pressing any button first connects the battery, then the galvanometer.

The control buttons may be locked on by pressing then rotating a quarter turn.

- - - - - -

Mounting:

The instrument is mounted in a sturdy splash-proof metal case with removable gasketed lid.

The case is especially designed for field use, and is provided with an extension strap for carrying from the shoulder.

- - - - - -

Dimensions:

The over-all size of the bridge, including the lid, is approximately 4 1/2" x 4 1/2" x 9 1/2".

- - - - - -

Weight:

Approximately 5 1/2 pounds net, including batteries.

The shipping weight is approximately 8 pounds.

5. PREVENTATIVE MAINTENANCE

A monthly check and a yearly maintenance program will insure a long trouble-free bridge life.

5.1 MONTHLY CHECK ITEMS

Item No.	What To Check	How To Check	Precautions
1	Panel, dials, knobs	Clean with soft brush.	
2	Binding posts and insulators	Clean off wax and dirt with soft cloth.	
3	Case and clamps	Rub down case with slightly oily cloth. Check, straighten and oil clamps and hinges.	
4	Oxide formed on switch contacts	Rotate each switch several times to assure good contact.	Bridge power must be turned off.
5	Battery and terminals	Clean corrosion and dirt on terminals with slightly oily cloth. Discard faulty cells. Check battery voltage.	Mark batteries with installation date.

5.2 YEARLY CHECK ITEMS

5.2.1 REMOVE THE CHASSIS FROM THE CASE

1. Prepare a soft, clean place to set the instrument. Be sure that no projections or pointed objects will be underneath the bridge panel. See that there are no metal filings around or above the exposed wiring and parts of the bridge. Filings accidently may fall into the chassis as a result of vibration or an inadvertent arm movement, and cause electrical short circuits.

2. Unscrew the six panel screws, lift out the chassis, and place it carefully, panel down, on the prepared surface.

5.2.2 YEARLY CHECKLIST

Item No.	What To Check	How To Check	Precautions
1	Wiring and solder joints	Look for loose wires, frayed and faulty insulation, loose and poor (rosin) solder joints.	
2	Resistors	Look for discoloration due to overheat.	
3	Push Switches	Check for proper engagement and continuity.	
4	Nuts on ends of basic assemblies	Moderately tight, secure with cement.	Do not get cement on contacts.
5	Clean and lubricate	All prescribed parts cleaned and lubricated	Look for fungus growths and mildew in tropical locations.

5.2.3 REPLACEMENT OF CHASSIS IN THE CASE

1. Be sure that the interior of the cabinet is thoroughly clean.
2. Position bridge in the cabinet.
3. Replace panel mounting screws and tighten them in place.

6. SERVICING AND REPAIR

NOTE: Unnecessary disassembly of the bridge may cause additional trouble instead of correcting existing trouble. Most of the bridge components can be checked without removing the chassis from the case.

If possible, the instrument should be returned to the factory or to an authorized service facility if trouble is suspected. If this is impractical the following procedure is recomended.

6.1 PRELIMINARY CHECKING

1. Check the panel controls to insure that they are positioned according to instructions covering the specific measurement being performed. It has been found in many cases that failure to obtain a bridge balance has been due to the wrong position of one or more of the panel controls.

2. Check connections between the bridge binding posts and the part under measurement. What appears to be an intermittent condition inside the instrument may be merely a poor outside connection.

3. Check the battery voltage and connections to the battery.

6.2 CHECKING PROCEDURE

NOTE: The bridge operator must acquire a knowledge of abnormal outside conditions that are reflected in unsatisfactory bridge operation so that tampering with the bridge will be avoided.

When it has been ascertained that the difficulty is not due to outside causes, the following procedures should be followed in conjunction with the trouble shooting chart. The measurements described in 6.2 should be made without removing the bridge chassis from the case.

CAUTION: Unqualified personnel must not tamper with the bridge. Unauthorized repairs will invalidate our warranty. If the tests outlined in the following paragraphs indicate the need for major repairs, our Service Department will be glad to furnish necessary repair information as well as any replacement parts. If the instrument is more than one year old, a reasonable charge may be expected for replacement parts or for complete reconditioning if the instrument is returned to the factory.

6.2.1 TEST EQUIPMENT AND TOOLS

Tool or test equipment	Use
A Wheatstone bridge	For accurate resistance measurements
A Multimeter	For voltage and resistance checking
Laboratory Resistance Standards	For checking accuracy of resistance readings
A Screw driver	To remove bridge from case
Allen-head wrenches, 1/16" hexagon	To loosen or tighten setscrews.

6.2.2 TROUBLE-SHOOTING CHART

Symptom	Probable cause of trouble	Procedure
Bridge inoperative	Defective battery	Test battery for proper voltage (6.2.3). If battery is defective, or if battery voltage under load is less than 4.2 volts, check individual cells. They should have more than 1.1 volts with a 10 ohm load.
Galvanometer will not come to zero	Faulty wiring	Check wiring to be sure that no short circuits exist.
Questionable operation	Faulty switch	Check all switches for proper contacts and operation.
Questionable operation	Open, shorted, or defective resistor	Test FUNCTION and RANGE for open and shorted circuits and rated values.
Questionable readings or erratic operation	Faulty DEKASTAT®	Check DEKASTAT® for continuity and for accuracy of resistance values corresponding to settings of DEKADIAL®.
No galvanometer movement with lock off	Defective galvanometer	Check galvanometer for proper operation.
Readings inaccurate	DEKASTAT® dials in wrong position on shaft.	Check DEKASTAT® dial location.

6.2.3 CHECKING THE BATTERY

1. Set the FUNCTION and RANGE switch to MURRAY 1,000.

2. Connect the Voltmeter positive (+) test lead to the GND binding post and the Voltmeter negative (-) test lead to the RH binding post. Connect a 1,000 ohm 1/2 watt resistor between the GND and RH binding posts.

3. Read the voltage as indicated by the Voltmeter. Normal voltage is 4.5 volts with a 1,000 ohm load.

   CAUTION: Do not have anything connected to the X_1 or X_2 terminal during the test and do not depress the SENSITIVITY PUSH BUTTONS.

4. If the battery voltage is low, inspect the batteries by removing the screws on the end of the case and taking off the battery cover.

5. Check each battery. The voltage should be greater than 1.1 volts with a 1/4 watt load resistor of 10 ohms.

6. Replace any low batteries.

7. If any batteries have leaked, remove all battery fittings. Wash the case and insulators with mild baking soda solution. Sand all affected paint off. Refinish with transparent plastic spray where necessary. Replace battery lead wires.

6.2.4 CHECKING THE FUNCTION AND RANGE RESISTORS

1. Release all sensitivity buttons.

2. Connect the Wheatstone Bridge to the EXT BAT (-) binding post and to the X_1 binding post. (See basic bridge circuit)

3. Check the readings with those on the following chart:

FUNCTION AND RANGE RESISTOR CHECK CHART

FUNCTION and RANGE Dial Setting	Resistance Between EXT BAT (-) and X_1 ±(.05% + .001Ω)
Resistance .001X	0.999
Resistance .01X	9.901
Resistance .1X	90.911
Resistance 1X	500.00
Resistance 10X	909.10
Resistance 100X	990.11
MURRAY 10, 100, 1000	1,000
VARLEY 1/9	100.00
VARLEY 1/4	200.00
VARLEY 1/1	500.00

6.2.5 CHECKING THE DEKASTAT®

The DEKASTAT® is used in making all bridge measurements. To check it, proceed as follows:

1. Release all SENSITIVITY PUSH BUTTONS. Do not have anything connected to the X_1 and GND terminals.
2. Connect the Wheatstone bridge leads to the X_2 and RH terminals.
3. Set all dials to zero.
4. Read the zero resistance R_o
5. Rotate each dial separately.
6. The bridge should read the value indicated by the DEKASTAT® dials plus the zero resistance R_o to an accuracy of $\pm(0.05\% + 0.007\Omega)$

6.2.6 CHECKING THE GALVANOMETER

1. Set the FUNCTION and RANGE switch to 100X.
2. Check the GALVANOMETER and SENSITIVITY PUSH BUTTON operation by setting the DEKASTAT® to the position indicated in the following chart and noting the meter deflection as the indicated button is pushed.

GALVANOMETER CHECK CHART

	SENSITIVITY PUSH BUTTON		
	Lowest (Green)	Middle (Yellow)	Highest (Red)
DEKASTAT® Setting	100	1,000	10,000
Meter Divisions	about 3	about 3	about 4

NOTE: If there is no GALVANOMETER deflection or if it is quite different from that above, check the shunt resistors (6.2.7) and the battery voltage (6.2.3) before replacing the galvanometer.

6.2.7 CHECKING THE SENSITIVITY RESISTORS

1. Set the FUNCTION and RANGE switch to MURRAY 1000.
2. Depress one of the EXT GALV terminals so that the internal galvanometer will be disconnected.
3. Check the 1000 ohm shunt resistor. With all SENSITIVITY buttons released, check for 1000 ohms resistance between the EXT GALV terminals. To prevent galvanometer damage be sure one EXT GALV terminal is depressed at all times that the resistance measuring equipment is connected.
4. Set the DEKASTAT® to 11,999.

5. Check the 100K series resistor. With only the left-hand (green) SENSITIVITY button depressed, check for 12.28K resistance between the EXT GALV (+) and X_2.

6. Check the 10K series resistor. With only the center (yellow) SENSITIVITY button depressed, check for 5.83K resistance between the EXT GALV (+) and X_2.

6.3 BRIDGE CHASSIS AND COMPONENTS

6.3.1 INSPECTION

The measurements covered in paragraphs 6.2.1 through 6.2.7 were made externally to eliminate the possibility of damage to the bridge caused by removing the chassis from the case. If further tests are necessary to locate trouble, and if adequate facilities are available, the bridge may be tested internally. To remove the bridge chassis from the case, see paragraph 5.2.1.

Referring to the basic bridge circuits and the schematic diagrams, use a Multimeter to test the various bridge circuits for continuity.

Continuity tests and resistor measurements are important aids in locating trouble, but be sure to consider and investigate the physical condition of switch contacts, switch arms, soldered connections, and other items covered in paragraph 5.2.2. Trouble may be caused by excessive oxidation on the switch contacts. When making continuity tests of the switches, check for short circuits, loose connections, corrosion, cold-soldered joints, etc., as possible causes of erroneous readings. Follow the instructions in the preventative maintenance checklist (5.1 and 5.2.2) for inspection, tightening and cleaning.

6.3.2 LUBRICATION

If switch lubrication is indicated, proceed as follows:

1. Apply a thin coating of special lubricant from esi with a hypodermic needle to the contact surfaces of the rotary switches. Do not use any other lubricant!

2. Apply 2 drops of the same oil to each of the switch bearings and detent mechanisms.

3. Remove excess oil with a clean, dry cloth and remove all traces of lint with a soft brush.

6.3.3 SETTING THE DIALS

In order to check that the dials are in their proper position with respect to the switch shaft they have been attached to, the following procedure can be carried out without difficulty.

6.3.3.1 DEKASTAT® DEKADIALS®

1. Attach an ohmmeter to terminals X_1 and RH.

2. Adjust the ohmmeter so that 1K increments are easily read.

3. Turn the left-hand outer dial clockwise (disregarding all other dials) through all 12 positions and note the position giving the lowest reading. This is the zero position. The left-hand outer dial must read "zero" at the right side of the dial.

4. Leave the left-hand outer dial at "zero" and adjust the ohmmeter to easily read 100 ohm increments.

5. Turn the right-hand outer dial clockwise through all 12 positions and note the position giving the lowest reading. This is the zero position. The right-hand outer dial must read "zero" at the left side of the dial.

6. Leave the left-hand outer and the right-hand outer dials at "zero" and adjust the ohmmeter to easily read 10 ohm increments.

7. Turn the right-hand middle dial clockwise through all 12 positions and note the position giving the lowest reading. This is the zero position. The right-hand middle dial must read "zero" at the left side of the dial.

8. Leave the left-hand outer, the right-hand outer and the right-hand middle dials at "zero" and adjust the ohmmeter to easily read 1 ohm increments. Turn the right-hand inner dial clockwise through all 12 positions and note the position of the lowest reading. This is the "zero" position. The right-hand inner dial must read "zero" at the left side of the dial.

6.3.3.2 FUNCTION AND RANGE DIAL

1. Attach an ohmmeter to terminals X_1 and EXT BAT (-)

2. Disregard the DEKASTAT® setting.

3. Turn the FUNCTION and RANGE dial through all 12 positions and note the position giving the lowest reading (about 1 ohm). This is the .001X position. The FUNCTION and RANGE dial must read "Resistance .001X" at the right side of the dial.

4. In order to d uble-check this FUNCTION and RANGE dial setting, attach the ohmmeter leads to terminals RH and EXT BAT (-).

5. Turn the FUNCTION and RANGE dial through all 12 positions. "Zero" ohm readings should be obtained at the MURRAY 10, 100 and 1000 dial positions.

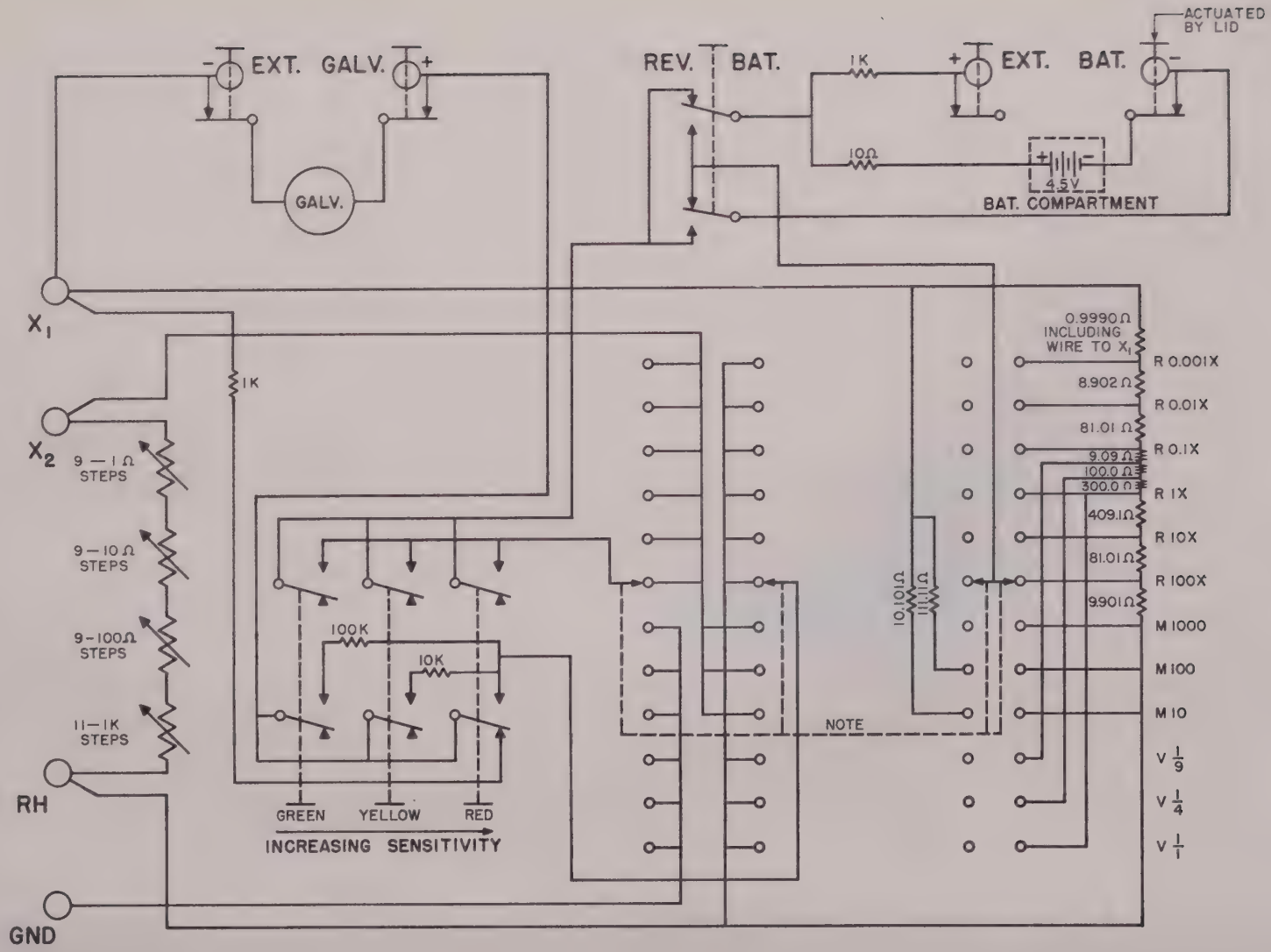
6.3.4 REFINISHING THE CASE

Whenever the panel or cabinet has been scarred or damaged, repair the outer surface to prevent corrosion of the metal. The scarred surface should be cleaned down to the bare metal with No. 00 or No. 000 sandpaper to obtain a bright, smooth finish. The bare spots should then be touched up with suitable paint.

CAUTION: Do not use steel wool instead of sandpaper. Small particles of the steel wool may enter the case and cause electrical shorting or grounding of the circuit.

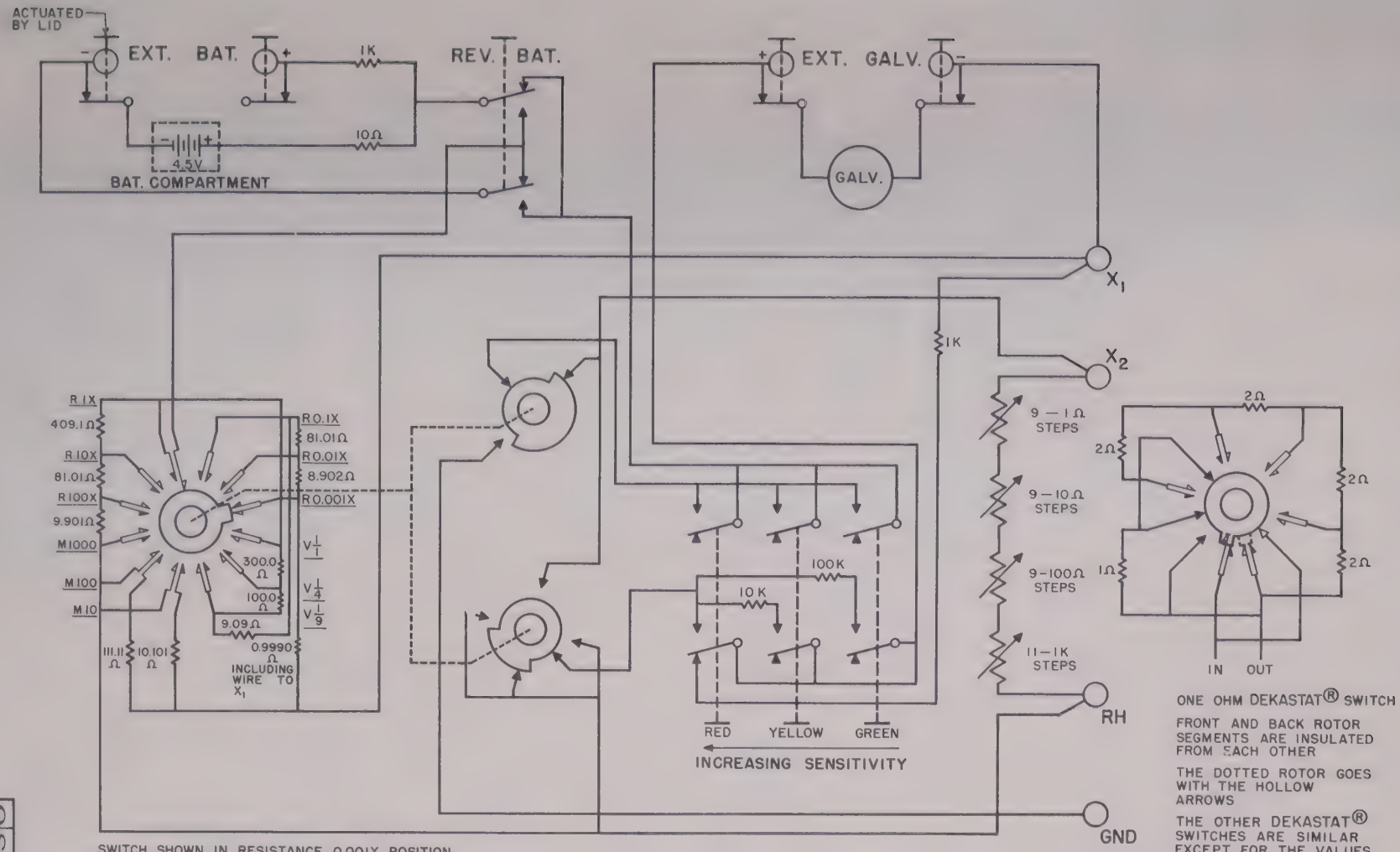
ANNEALED COPPER WIRE TABLE

B & S Gauge	B Feet per Ohm 20°C (68° F)
. . .	47,270
. . .	37,810
. . .	33,090
. . .	28,360
. . .	23,630
0000	20,400
000	16,180
00	12,830
0	10,180
1	8070
2	6400
3	5075
4	4025
5	3192
6	2531
7	2007
8	1592
9	1262
10	1001
11	794
12	629.6
13	499.3
14	396.0
15	314.0
16	249.0
17	197.5
18	156.6
19	124.2
20	98.5
21	78.11
22	61.95
23	49.13
24	38.96
25	30.90
26	24.50
27	19.43
28	15.41
29	12.22
30	9.69



NOTE:
RANGE-FUNCTION SWITCH IS ILLUSTRATED FUNCTIONALLY AND DOES NOT REPRESENT ACTUAL SWITCH CONFIGURATION

7.2 BRIDGE CIRCUIT DIAGRAM



SWITCH SHOWN IN RESISTANCE 0.001X POSITION

SWITCH SECTIONS AS SEEN FROM BEHIND THE PANEL

SOLID SWITCH CONTACT ARROWS ARE ON THE SIDE FARTHEST FROM THE PANEL
HOLLOW ARROWS REPRESENT CONTACTS ON THE SIDE NEAREST THE PANEL

FRONT AND BACK ROTOR ARE THE SAME AND CONNECTED

ONE OHM DEKASTAT® SWITCH

FRONT AND BACK ROTOR SEGMENTS ARE INSULATED FROM EACH OTHER

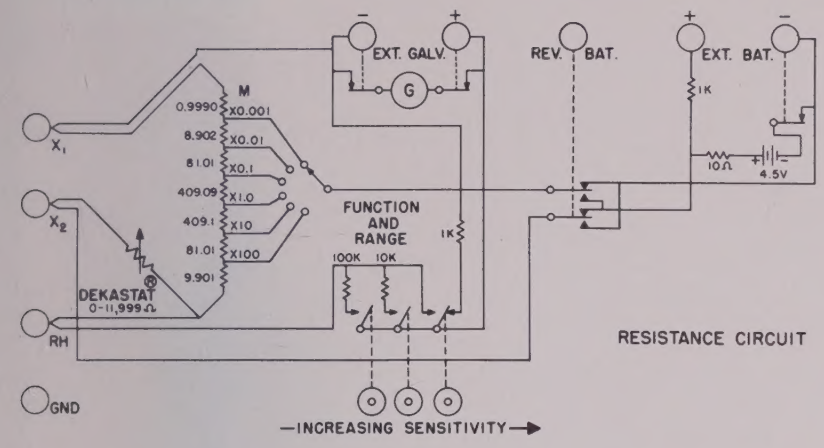
THE DOTTED ROTOR GOES WITH THE HOLLOW ARROWS

THE OTHER DEKASTAT® SWITCHES ARE SIMILAR EXCEPT FOR THE VALUES OF THE RESISTORS AND ONE MORE RESISTOR ON THE 1K DECK

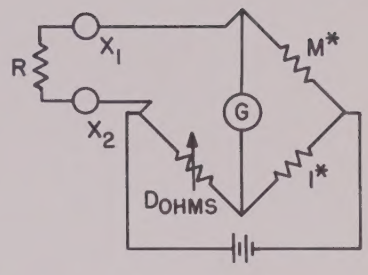
SWITCH SHOWN IN ZERO POSITION

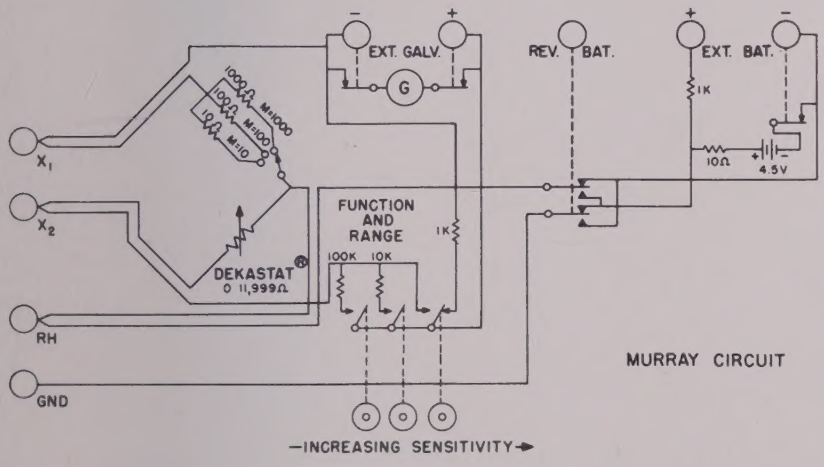
7.3 BRIDGE MAINTENANCE DIAGRAM

7.4 RESISTANCE, MURRAY, AND VARLEY DIAGRAMS

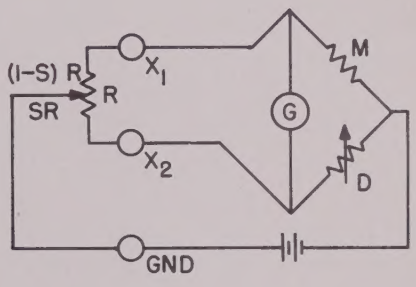


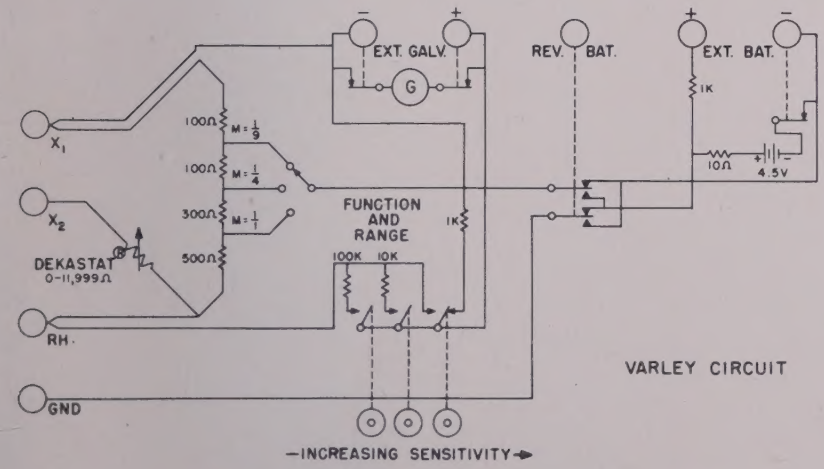
RESISTANCE CIRCUIT



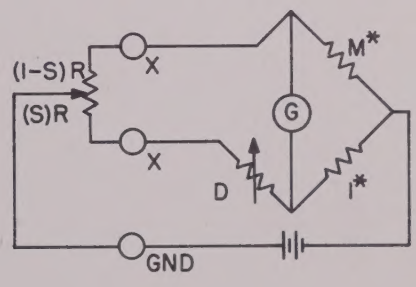


MURRAY CIRCUIT





VARLEY CIRCUIT



*Since only the ratio of these resistors is involved in the bridge balance equation they have been shown this way for simplicity. The actual values can be found in the complete diagrams.

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